

Comparative Study of the Blood Biochemistry of Three Species of
Indian Carp

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ABSTRACT

Samples of three species of Indian carp, *Catla catla*, *Cirrhina mrigala*, and *Labeo rohita*, were examined when they were 480 days old by biochemical tests and electrophoresis of the blood and plasma. The three species did not differ significantly in total plasma protein (micro-Kjeldahl), relative amounts of total plasma protein and total lipoprotein, and plasma albumin. Significant differences were found in body weight, blood sugar, α_1 , α_2 , β , and γ -globulin fractions from the plasma, and lipoprotein fractions. Electrophoretic studies revealed two qualitatively different components: a second hemoglobin band in *Catla catla*, and a third lipoprotein fraction designated α_F in *Cirrhina mrigala*. The three species were found to differ significantly when weight, blood sugar, α_1 , α_2 , β , and γ -globulin fractions from the plasma were considered simultaneously.

The purpose of the present investigation was to describe quantitatively the biochemical constituents of the blood for several species of fresh-water carp of India, and to determine whether these constituents exhibit species differences. This investigation was part of a larger inquiry on fresh-water carp of India being carried out in this laboratory (Chandrasekhar, 1959; Das, 1959; Das and Krishnamurthy, 1959).

The literature does not reveal any data on blood constituents as sugar, plasma protein fractions, lipoprotein fractions, and hemoglobin in Indian fresh-water carp. General studies on the blood biochemistry of fishes are lacking (Williams, 1951) and no data on blood are given in Love's review of the biochemical composition of fish (Brown, 1957). Three species of Indian carp, *Catla catla* (Ham.), *Cirrhina mrigala* (Ham.), and *Labeo rohita* (Ham.), were chosen for examination. Biochemical determinations of blood sugar and total plasma protein, and electrophoretic studies of plasma protein fractions, lipoprotein fractions, and hemoglobin were carried out on random samples of each species. Species differences were examined using the analysis of variance and discriminant function analysis (Lao, 1952; Snedecor, 1956).

MATERIALS AND METHODS

Three hundred Indian carp fingerlings of each of three species (*Catla catla*, *Cirrhina mrigala*, *Labeo rohita*), which had been raised in the laboratory from the embryonic stage, were placed in a natural pond (in Baranagar, 24-Parganas, West Bengal, India) at 1 month of age. This pond was 45 feet wide, 270 feet long, and 15 feet deep along the central line. Two months before fingerlings were placed in the pond, all the fish present were removed, and the pond was thoroughly cleaned and fertilized with the oil cake—residue from extraction of oil from mustard seeds. No other artificial food was added.

When the fish were 480 days old, a random sample of 12 fish representing both sexes equally was taken from each species. At this age the fish had completed the stage of rapid growth but were not sexually mature. Weight of each fish was recorded in grams. Blood was taken from the heart of each fish, and was treated with heparin to prevent coagulation. Chemical and electrophoretic measurements were made for each fish individually.

Blood sugar was tested by King's modification of Harding's modification of the Schaffer-Hartmann method which estimates true glucose

TABLE 1.—Means and standard deviations of weight, biochemical tests, and electrophoretic measurements of blood of *Cirrhina mrigala*, *Labeo rohita*, and *Catla catla*

[12 fish of each species were used]

Measurement	<i>Cirrhina mrigala</i>		<i>Labeo rohita</i>		<i>Catla catla</i>	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Weight (grams)	521.00	201.77	665.08	88.03	1,035.17	447.98
Blood sugar (milligrams per 100 milliliters)	92.96	9.12	95.34	14.29	67.29	8.17
Total plasma protein in grams per 100 milliliters (micro-Kjeldahl)	2.69	0.34	2.87	0.46	3.11	0.45
Plasma albumin (percentage)	44.67	11.80	46.17	7.94	42.58	9.27
α_1 plasma globulin (percentage)	32.59	11.03	20.42	8.58	8.83	3.52
α_2 plasma globulin (percentage)	13.67	9.06	13.83	6.08	15.17	4.30
β plasma globulin (percentage)	5.50	4.31	6.83	2.82	26.00	2.72
γ plasma globulin (percentage)	3.58	1.93	12.75	7.93	10.42	5.77
α_F lipoprotein (percentage)	7.17	3.24	—	—	—	—
α lipoprotein (percentage)	38.33	8.21	77.80 ¹	7.88 ¹	53.11 ²	18.89 ¹
β lipoprotein (percentage)	54.50	6.96	22.20 ¹	7.88 ¹	46.89 ²	18.89 ¹
Plasma albumin (gm/100 ml)	1.12	0.65	1.29	0.61	0.99	0.23
α_1 plasma globulin (gm/100 ml)	0.80	0.42	0.62	0.39	0.21	0.09
α_2 plasma globulin (gm/100 ml)	0.33	0.26	0.37	0.16	0.41	0.22
β plasma globulin (gm/100 ml)	0.13	0.08	0.18	0.08	0.58	0.22
γ plasma globulin (gm/100 ml)	0.09	0.06	0.34	0.18	0.28	0.22
Total plasma protein (electrophoresis)	2.47	1.13	2.80	1.16	2.47	1.07
α_F lipoprotein (gm/100 ml)	0.14	0.05	—	—	—	—
α lipoprotein (gm/100 ml)	0.83	0.46	1.26 ¹	0.75 ¹	1.20 ²	0.87
β lipoprotein (gm/100 ml)	1.15	0.49	0.34 ¹	1.12 ¹	1.04 ²	0.72
Total lipoprotein (electrophoresis)	2.12	0.92	1.60 ¹	0.85 ¹	2.24 ²	1.10

¹ 10 fish were used.² 9 fish were used.

in milligrams per 100 milliliters of blood (King and Wooten, 1956). Total plasma protein was estimated by a micro-Kjeldahl method which gives the total protein in grams per 100 milliliters (Hawk, Oser, and Summerson, 1954; Hepler, 1949).

Plasma protein fractions were determined by the agar electrophoresis method of Giri (1956). The materials used were agar fine powder, veronal acetate buffer, Amido Schwarz dye solution, and Whatman No. 1 and 3 papers. In this investigation the agar electrophoresis unit which was used was made by the Vega Corporation, Bangalore, India, and the photovolt densitometer by the Photovolt Corporation, New York. The blood was prepared by clotting at 37° C. for 1 hour in sterile pyrex tubes, after which it was centrifuged at 2,500 r.p.m. for 15 minutes. The agar plate was made by applying a sample of the resulting clear plasma to a Whatman No. 1 paper and placing it at the center of the agar gel solution on a glass plate. Another glass plate was then placed over the agar plate. The electrophoresis was carried out in the veronal acetate buffer for 5 hours at 220 volts, 5 milliamperes, after which the agar plate was dried and stained. Densitometric curves were obtained by measuring the color density of the protein fractions on the agar plate with the photovolt densitometer. Relative amounts of the protein fractions were estimated by

measuring the densitometric curves with a planimeter.

Lipoprotein fractions were also estimated for the clear plasma using the agar electrophoresis method described above. Instead of Amido Schwarz dye, the dry agar plate was stained with Sudan Black. Relative amounts of the lipoprotein fractions were estimated by measuring the densitometric curves with a planimeter. Hemoglobin mobility was also determined by the agar electrophoresis method described above. Electrophoresis was carried out for 8 hours instead of 5 hours and the bands were evaluated qualitatively.

LEVELS OF BLOOD COMPONENTS

Means and standard deviations for weight and biochemical and electrophoretic measurements are presented in Table 1 for *Catla catla*, *Cirrhina mrigala*, and *Labeo rohita*. Measurements of the densitometric curves gave the relative amounts of the plasma protein fractions (albumin, α_1 -globulin, α_2 -globulin, β -globulin, and γ -globulin). The total area under the densitometric curve is reported as total plasma protein (electrophoresis), and dividing the relative amounts of the fractions by the total amount gave percentage values of the plasma protein fractions. The same procedure was used to obtain the relative amounts and percentage values of the lipoprotein fractions α and β . Figure 1 presents

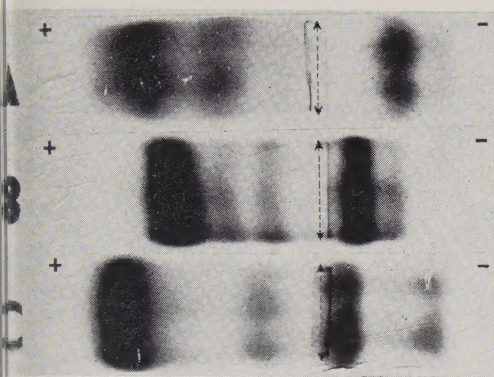


FIGURE 1.—Electrophoretic patterns of plasma protein fractions on agar plates for *Cirrhina mrigala* (A), *Labeo rohita* (B), and *Catla catla* (C). The broken vertical line on each plate indicates the point of insertion. The anode is at the left side and the cathode at the right side. From left to right are the albumin, α_1 -globulin, α_2 -globulin, β -globulin, and γ -globulin fractions.

The electrophoretic pattern of the plasma protein fractions on the agar plates for *Cirrhina mrigala*, *Labeo rohita*, and *Catla catla*. Figure 2 presents the densitometric curves of the electrophoretic patterns in Figure 1. It will be noted from Table 1 that one lipoprotein fraction, designated α_F , was obtained for *Cirrhina mrigala* but was not found in *Catla catla* and *Labeo rohita*. This component had a higher electrophoretic mobility than α -lipoprotein.

A qualitative analysis of the electrophoretic pattern was carried out for hemoglobin. *Catla catla* was found to have two bands, while

Labeo rohita and *Cirrhina mrigala* had only one band.

An analysis of variance was computed (Table 2) for each of the measurements given in Table 1 which were available for all three species. Differences between species were statistically significant for the following 12 measurements: weight, blood sugar, α_1 -, β -, and γ -globulins (percentage values), α - and β -lipoproteins (percentage values), and relative amounts of the four globulins and β -lipoprotein.

Discriminant function analysis was used to determine whether the species differed significantly on a combination of weight, blood sugar, and relative amounts of α_1 , α_2 , β , and γ -plasma globulins. The statistic

$$V = -m \log_e \Lambda, \quad \Lambda = \frac{|W|}{|W + Q|}$$

(Rao, 1952, p. 258)¹ was computed. For the present data, $\Lambda = 0.069999$, $m = 30.5$, and $V = 81.15$. Treating V as chi square with 12 degrees of freedom, the hypothesis of the equality of the means on the combined measures was rejected ($P < 0.001$).

Similarities between the three species were observed for total plasma protein (micro-

¹ For the statistic $V = -m \log_e \Lambda$, $m = n + (p + q + 1)/2$ where n = total number of cases minus 1, p = number of groups minus 1, q = number of measurements, and $\Lambda = |W| / |W + Q|$ where $|W|$ is the determinant of the within sum of products matrix and $|W + Q|$ is the determinant of the total sum of products matrix.

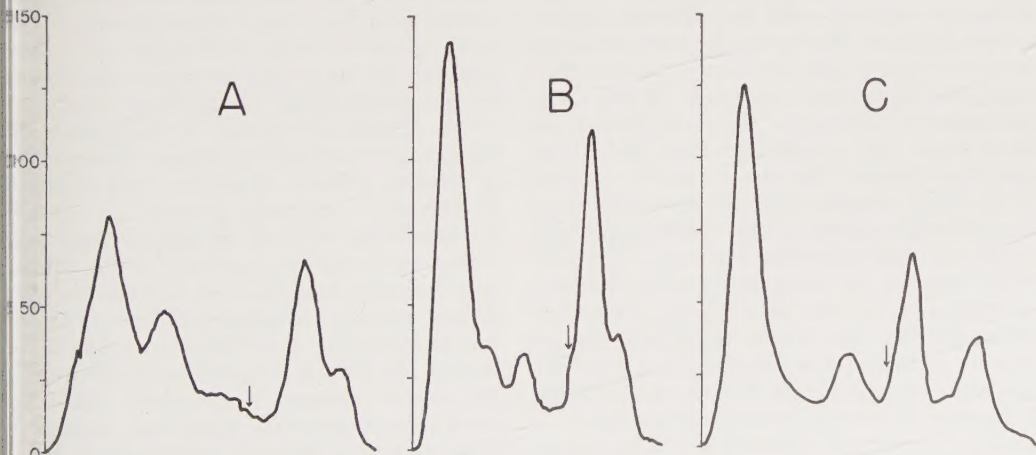


FIGURE 2.—Densitometric curves for plasma protein fractions (A) of *Cirrhina mrigala* from the electrophoretic plate in Figure 1, A; (B) of *Labeo rohita* from Figure 1, B; (C) of *Catla catla* from Figure 1, C. The albumin fraction and globulin fractions α_1 , α_2 , β , and γ appear when the graphs are read from left to right.

TABLE 2.—Analysis of variance summary tables comparing weight, biochemical tests, and electrophoretic measurements of blood of *Cirrhina mrigala*, *Labeo rohita*, and *Catla catla*

Measurement	Source of variation	Sum of squares	d.f.	Mean square	F
Weight	Between groups	1688356.17	2	844178.08	9.319
	Within groups	2989456.58	33	90589.59	
Blood sugar	Between groups	5805.65	2	2902.82	22.541
	Within groups	4249.77	33	128.78	
Total plasma protein (micro-Kjeldahl)	Between groups	1.19	2	0.60	3.158
	Within groups	6.24	33	0.19	
Plasma albumin (percentage)	Between groups	77.72	2	38.86	0.363
	Within groups	3534.97	33	107.12	
α_1 plasma globulin (percentage)	Between groups	3385.06	2	1692.53	22.418
	Within groups	2491.50	33	75.70	
α_2 plasma globulin (percentage)	Between groups	16.22	2	8.11	0.162
	Within groups	1656.00	33	50.18	
β plasma globulin (percentage)	Between groups	2277.55	2	1138.78	92.433
	Within groups	406.67	33	12.32	
γ plasma globulin (percentage)	Between groups	544.67	2	272.34	7.505
	Within groups	1198.08	33	36.30	
α lipoprotein (percentage)	Between groups	8559.94	2	4279.97	25.809
	Within groups	4643.16	28	165.83	
β lipoprotein (percentage)	Between groups	6009.99	2	3005.00	19.058
	Within groups	4415.49	28	157.70	
Plasma albumin (gm/100 ml)	Between groups	0.56	2	0.28	0.879
	Within groups	10.40	33	0.32	
α_1 plasma globulin (gm/100 ml)	Between groups	2.19	2	1.10	9.179
	Within groups	4.02	33	0.12	
α_2 plasma globulin (gm/100 ml)	Between groups	0.04	2	0.02	3.338
	Within groups	2.11	33	0.06	
β plasma globulin (gm/100 ml)	Between groups	1.46	2	0.73	18.258
	Within groups	1.21	33	0.04	
γ plasma globulin (gm/100 ml)	Between groups	0.40	2	0.20	6.678
	Within groups	1.04	33	0.03	
Total plasma protein (electrophoresis)	Between groups	0.81	2	0.40	0.290
	Within groups	45.40	33	1.38	
α lipoprotein (gm/100 ml)	Between groups	1.18	2	0.59	1.161
	Within groups	14.27	28	0.51	
β lipoprotein (gm/100 ml)	Between groups	3.98	2	1.99	7.118
	Within groups	7.86	28	0.28	
Total lipoprotein (electrophoresis)	Between groups	2.30	2	1.15	1.101
	Within groups	29.44	28	1.05	

° P < .05

°° P < .01

Kjeldahl), relative amounts of total plasma protein and lipoprotein (measured from densitometric curves), and the albumin plasma protein fraction. Marked differences occurred for blood sugar, globulin plasma protein fractions, and lipoprotein fractions. While *Catla catla* was the heaviest of the three species, its blood sugar was notably less than that of the other two species. The electrophoretic pattern of *Cirrhina mrigala* differed markedly from that of *Catla catla* and *Labeo rohita*, especially on the α_1 - and γ -globulin fractions. For *Cirrhina mrigala* an extra lipoprotein fraction, designated as α_F , was also found. While *Cirrhina mrigala* and *Catla catla* had similar values for the β -lipoprotein fraction, this fraction was considerably smaller in *Labeo rohita*. A further difference between species was observed in electrophoresis of the hemoglobin. Two bands characterized *Catla catla* but only one band was found in *Cirrhina mrigala* and *Labeo rohita*.

Differences and similarities between quantitative measurements of some blood and plasma constituents have been demonstrated for the three species of carp. It remains to be shown whether the three species differ significantly in the combination of different constituents of the plasma and blood. In the present data blood sugar and electrophoretic measurements of plasma globulin fractions were combined to provide a composite picture. To control possible effect of body weight on these measurements, it was also included in the discriminant function analysis, which takes the correlations between measurements into consideration in evaluating the differences between the means. As the test of significance showed that the means differed significantly when they were considered at the same time, species differences among the carp in the composition of blood and plasma are suggested. Quantitative biochemical and electrophoretic measurements may be expected to assist in the understanding

fish physiology and species differences in the future.

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Regular Occurrence of False Annuli in Four Brook Trout Populations

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ABSTRACT

False annuli were found in 65 to 90 percent of brook trout (*Salvelinus fontinalis*) specimens of several year classes sampled in four Adirondack lakes. Maximum age of fish present was known since all four lakes were recently reclaimed. One or two false annuli were found on scales of trout planted as advanced fry or hatched from eggs deposited naturally. A method of identifying accessory checks based on scale measurements was developed for determining age of these trout. Influence of environmental temperature on growth rate is discussed as a possible explanation for formation of false annuli.

INTRODUCTION

Age determinations based on scale studies have become so widely used by fishery biologists that certain scale characteristics may often be accepted as annular markings without further study. Validity of annuli may be established by comparing age distributions taken from scale studies to length-frequency distributions for the same populations, but unless known-age fish are available, it is seldom possible to validate annuli with certainty. Information on accessory checks in brook trout has received little notice in recent literature on age and growth. Cooper (1951) mentions two instances of false annuli on trout from Michigan streams. Allen (1956) validated annuli on scales of brook trout from a Wyoming beaver pond without encountering false annuli. Alvord (1954) validated only those annuli formed between tagging and recapture. He attributes occasional formation of checks to trauma in original capture and handling while tagging.

An age-and-growth study on brook trout, *Salvelinus fontinalis* (Mitchill), in four recently reclaimed Adirondack lakes revealed the regular formation of false annuli in all four trout populations. East Lake, Panther Lake, and Upper and Lower Sylvan Ponds are located in Herkimer County, New York. Morphometric, physical, and chemical features of these waters are summarized in Table 1. Semi-annual inventories of trout populations in these waters were carried out from 1955 to 1958 in connection with production studies. Trap and gill nets, fixed stream traps, and electrofishing gear were used to collect ma-

terial. Scale samples were taken from the caudal peduncle below the adipose fin. Scales were either mounted in water under a cover glass or impressed on cellulose acetate for study. All readings and measurements were taken on a back-projection device at a magnification of 84.65 diameters. Scale measurements recorded herein are those of the magnified scale image.

Annular characteristics of brook trout scales listed by Cooper (1951), which included sudden change in growth pattern of circuli characterized by crowding followed by wide spacing, irregular or incomplete circuli, and crowding over in lateral fields, were used to define annuli. Scale configurations which conformed to these characteristics were regarded as checks until they were validated as annuli.

OCCURRENCE OF FALSE ANNULI ON SCALES

East Lake

East Lake was reclaimed with rotenone in October 1954 and restocked with advanced fry (1 inch) and fin-clipped yearling brook trout in May 1955. Fin-clipped fingerlings have been stocked annually in the fall since September 1955. Considerable numbers of naturally produced trout of the 1956 and later year classes are also found in the population. Early in the study of East Lake trout scales it became apparent that false annuli were being formed with considerable regularity. In 1956, 70 and 65 percent of scales read from East Lake in spring and fall samples, respectively, indicated that trout of age-groups I and III were present, but only age-group II and I were actually available. The 1956 year class was the only group of unmarked fish that was completely vulnerable to trap net sampling throughout 1956. The 1956 year class was not vulnerable to sampling except by stream traps in the fall of 1956. Reclam-

¹ Based on part of a doctoral dissertation submitted to the faculty of the Graduate School, Cornell University.

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TABLE 1.—*Morphometric, physical, and chemical characteristics of four Adirondack lakes from which trout were taken*

Measurement	East Lake	Lower Sylvan Pond	Upper Sylvan Pond	Panther Lake
Area (acres)	31.9	16.8	12.2	41.6
Maximum depth (feet)	36	18	33	20
Average depth (feet)	14.3	9.4	12.7	11.0
Average pH	7.0	6.8	6.8	7.1
Total alkalinity (p.p.m.)	8.2	3.0	3.3	8.6
Summer stratification	Yes	No	Yes	No
Uchi-disk depth (feet)	12	18	21	20
Contributory streams	2	1	0	0

was considered to be completely successful in the lake since only a single minnow has been seen in East Lake during the 5 years following treatment. Before reclamation, bullheads (*Ictaluridae*), suckers (*Catostomidae*), and minnows (*Cyprinidae*) dominated the lake fish fauna. Trout eggs already in the gravel in a tributary of the outlet at the time of reclamation survived, but trout hatching from these eggs would belong to the 1955 year class and would appear as age I in 1956. The problem of defining true and false annuli is discussed in detail for trout from East Lake because large samples are available. Further samples of false annulus formation are then demonstrated in the other three waters studied. The numbers of checks found on scales of trout of various sizes in the 1955 year class during three sampling periods in 1956 are shown in Table 2. Only the smallest fish in the May sample failed to show checks. In the

TABLE 2.—*Frequency of occurrence of checks in spring, summer, and fall samples of 1955 year class trout taken from East Lake in 1956*

[Summarized by total length groups]

Total length (nearest inch)	No checks	One check	Two checks	Three checks
Spring				
4	11	6	0	0
5	0	0	0	0
6	0	3	0	0
7	0	11	1	0
8	0	6	0	0
9	0	1	0	0
Summer				
5	0	1	1	0
6	0	0	3	0
7	0	0	4	0
8	0	2	8	0
9	0	0	0	0
10	0	0	1	0
Fall				
5	0	9	0	0
6	0	13	6	0
7	0	15	25	0
8	0	0	14	4
9	0	0	5	9
10	0	0	3	5

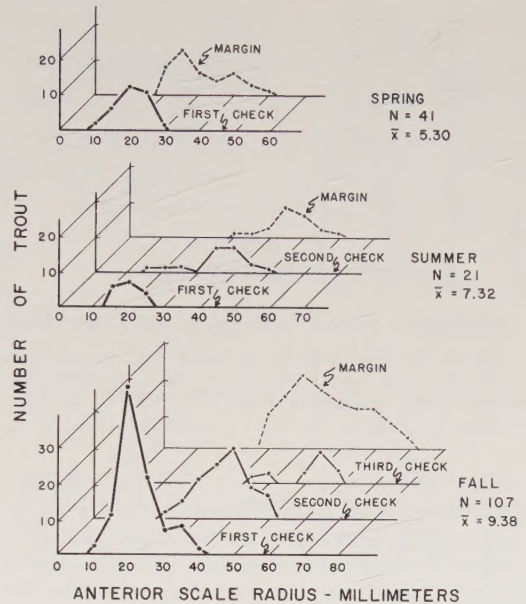


FIGURE 1.—Formation of checks on scales of 1955 year class, East Lake. Frequency of occurrence of first, second, and third checks in 5-millimeter intervals from center of scale focus indicated in three samples taken in 1956. Sample size indicated by N; mean total length by $\bar{x}$.

summer sample, all fish showed one check and 85 percent showed two checks. In the fall sample, 34 percent showed one check, 49 percent two checks, and 17 percent three checks although these fish were not more than age I+.

Frequency of occurrence of checks along the mid-anterior scale radius was plotted (Figure 1) to determine which checks were true annuli and which represented only a change in growth during the year. The May sample (taken 1 week after ice cover broke up) showed that the scale margin at the beginning of spring growth was rarely less than 20 millimeters from the center of the focus. Location of the scale margin in the 1956 year class sampled in the fall of 1956 supported this observation (Figure 2). In this sample (98 trout) nine fish had scale margins less than 20 millimeters from the center of the focus, and two had margins less than 18 millimeters from the center. Three of the nine fish had a check well within the margin. It appears, therefore, that formation of a true annulus less than 20 millimeters from the center of scale focus was seldom possible in the 1955 year class.

In the 1956 year class, a true annulus could seldom occur less than 18 millimeters from the

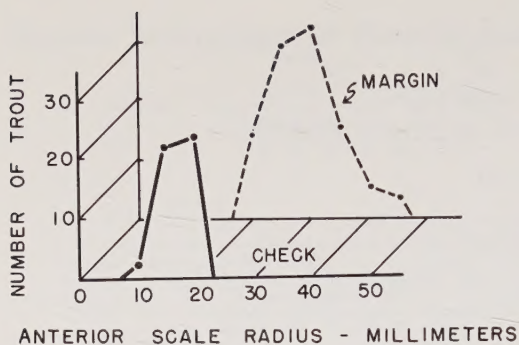


FIGURE 2.—Distribution of check and margin on scales of 1956 year class, East Lake, sampled by stream traps, November 1956. $N = 98$; $\bar{x} = 4.35$ inches.

center of the scale focus. Any annulus-like pattern less than 20 millimeters from the focus in the 1955 year class, or less than 18 millimeters from the focus in the 1956 year class, must therefore be interpreted as an accessory growth check. A pictorial record of formation of checks and annuli on scales of the 1955 year class in East Lake is shown in Figure 3. Age designation for each scale is the oldest that could be attained by the first

trout stocked after reclamation. Figure 3B shows a check on a scale taken in fall 1956 5 months after initial stocking of advanced fry. An accessory check is also clearly visible in Figure 3C. Figure 3B shows a trout scale of the same age and taken at the same time as the one in Figure 3C, but without a check.

The first true annulus is shown in Figure 3E, summer sample. In this and in the fall sample, distribution of the second check corresponded well with the distribution of scale margins in May. The second check, therefore, was regarded as the true annulus on all fish showing more than one check in fall 1956. Both the check and annulus are shown in Figure 3F. The distributions of first and second checks overlap (Figure 1). The first check was regarded as the true annulus on fish showing only this mark (Figure 3F) unless it was less than 20 millimeters from the focus. The fish were the smallest sampled in May, which showed no check (Table 2, Figure 3B). Occurrence of an accessory check in scales of the 1956 year class (Figure 2) indicates formation of a check was not peculiar to a particular year class or growing season. In this case, also, location of the check on large



FIGURE 3.—Scales of East Lake brook trout of the 1955 year class (X 38). True annuli indicated Roman numerals, false annuli (checks) by X. Date of capture and total length at capture indicated below each scale photograph.

les overlapped location of the margin on smaller scales. A second accessory check on scales of some members of the 1955 year class (Table 2, Figure 3E) is close to the margin in 1956 samples and is not as clear as the check formed during the first growing season. It could ordinarily be regarded as an annulus only if the population in question were known to have a very low growth rate.

There was some difficulty in separating the 1955 and 1956 year classes in 1957 samples. Many members of the 1956 year class had checks at a 20-millimeter radius from the scale focus (Figure 2). Most members of this group had scale margins 30 millimeters or more in radius in fall 1956. The true annulus for this group should, in general, be 30 millimeters or less from the scale focus. Annuli more than 30 millimeters in radius were rare in the 1955 year class (Figure 1).

The procedure of age determination adopted to use with 1957 samples involved measurement of distance of various checks from the scale focus at 85 diameters magnification. Any check less than 18 millimeters from the center of the focus was rejected as an accessory check, and age was assigned accordingly. Scales were assigned to other trout according to the following key for scale measurements:

Only two checks present, both less than 30 millimeters from center of scale focus 1956 year class

A. Two or more checks present; if only two, one more than 30 millimeters from center of scale focus B.

B. First check less than 20 and second more than 30 millimeters from center of scale focus (comparatively rare) 1956 year class

BB. First check more than 20 and second more than 30 millimeters from center of scale focus 1955 year class

This system undoubtedly produced some misclassifications. Since both the inner accessory check and first annulus fulfilled the description of an annulus, it was necessary to set up these arbitrary rules for deciding age in individual cases. Age distributions of East Lake fish resulting from this procedure are presented in Hatch and Webster (in press). Further sampling in East Lake streams during 1958 showed a similar pattern of development of scale characters in the 1958 year class. A sample was taken in July from a stream trap near the mouth of the lake inlet. Additional samples were taken by electrofishing in August, September, and November from the mouth to a point about 200 yards upstream.

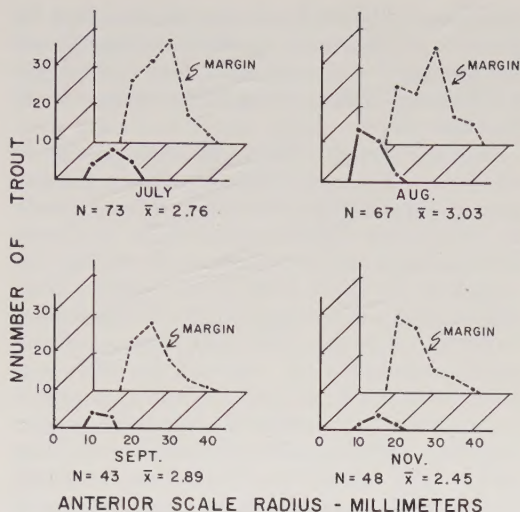


FIGURE 4.—Development of scale characters of 1958 year class, East Lake, as shown by four samples taken during 1958.

Some fish in these samples (Figure 4) had an accessory check on the scales varying between 10 and 20 millimeters from the focus. Since scale measurements did not increase in later samples, absence of growth was indicated. Mean length of trout sampled in September and November was less than mean length in August. Presumably this apparent lack of growth was a result of continuous movement of larger fish from stream to lake throughout the summer. Five percent of 140 fish taken in July and August (1.3 to 1.9 inches total length) had not yet formed scales, but even the smallest of 43 trout taken in September (1.7 inches) had scales. No scales less than 8 millimeters in radius were seen.

Sylvan Ponds

Upper and Lower Sylvan Ponds are connected by a short stream. Both were reclaimed in October 1952 and restocked with advanced fry in June 1953. Additional plantings of advanced fry were made in 1954 and 1955. Fin-clipped fall fingerlings were planted in 1955 and 1956.

Regular formation of false annuli also took place in trout from the Sylvan Ponds. Three scale samples taken in Lower Sylvan Pond in October 1953, 4 months after initial restocking, showed checks within the margin. Scales were taken from 18 trout in the Sylvan Ponds in 1954. At least two checks were found in 85 percent of these samples, although age I+ was the oldest age possible in 1954. Scale

studies of fall 1955 samples showed that 92 percent of fish taken in both Sylvan Ponds had at least two checks within the margin (37 percent of those from Lower Sylvan Pond had three).

Age II+ trout could have been present in the Sylvan Ponds in 1955, but not in the frequency suggested by the fall samples. Growth in the Sylvan Ponds, particularly in Lower Sylvan Pond, is faster than in East Lake. A sample of yearlings from Lower Sylvan Pond in fall 1954 had a mean length of 10.5 inches, indicating that the 1953 year class was completely vulnerable to angling in 1955 and mostly vulnerable in 1954. Of 20 tags placed in this sample, five were recovered by anglers in 1955, indicating that the 1953 year class was heavily harvested prior to the inventory in fall 1955. Only three of these tags were recovered in 1956 (two in spring trap netting, one by angling) and none since that time. This evidence suggests that the majority of trout sampled by nets in fall 1955 and spring 1956 were members of the 1954 year class. One of the checks on the scales of this group must again be regarded as a false annulus.

Distribution of inner checks along the anterior scale radius in Sylvan Ponds' trout was quite similar to that for East Lake. Since it was not possible to sample fish less than 6 inches long adequately in these waters, a lower limit could not be set for scale margins at the end of the first growing season. The smallest fish taken in stream samples (6 inches) had scale margins at least 30 millimeters from the center of the scale focus. It is therefore assumed that, as in the slower growing East Lake population, any annulus-like check less than 20 millimeters from the focus must be an accessory check; and that marks between 20 and 25 millimeters would be subject to question. Fish whose scales fall into the latter category were extremely rare in Upper Sylvan Pond and made up less than 20 percent of the samples in Lower Sylvan Pond. They were placed in the appropriate age groups on the basis of total length compared with the distribution of lengths of fish in which age was assigned without this difficulty. Satisfactory age structures were derived for these populations using the criteria outlined above (Hatch and Webster, in press). A second accessory check was sometimes formed during the second growing season and occurred quite frequently in fish from Lower Sylvan Pond but only occasionally in those from Upper Sylvan Pond.

Panther Lake

Panther Lake was reclaimed in fall 1951 and restocked with yearlings and fingerlings in 1952. Fingerlings were planted in 1953 and advanced fry in 1954. Fin-clipped fall fingerlings were planted in 1955 and 1956. No clipped fish have been stocked since then representing the 1954 year class. Unclipped fish of later year classes are the result of natural reproduction and are relatively few in number. Accessory checks formed during the first growing season would be expected to appear only in the 1954 year class as a whole and in naturally spawned members of other year classes. This appears to be the case since an annulus-like mark less than 20 millimeters from the scale focus occurs mainly in a large group (interpreted as the 1954 year class) and in two smaller groups (interpreted as naturally produced members of the 1955 and 1956 year classes) which can be followed throughout the study on the basis of length frequency distribution. A pronounced check corresponding to summer 1955 appears on the scales of fish judged to belong to the 1953 and 1954 year classes. This check is believed to have resulted from a suspension of growth during late July and early August 1955, when very hot weather brought temperatures to a lethal level for brook trout (Webster, 1956). With the exception of these two checks, annuli were accepted as true year marks on scales of Panther Lake brook trout.

FORMATION OF FALSE ANNULI

The accessory check fulfills all criteria for an annulus and must, therefore, represent a change in growth rate. Temperature is an important factor which influences growth rate in fish.

Fry,⁴ summarizing knowledge on relation of temperature to growth in brook trout, indicates that optimal growth range is between 55° and 60° F. Baldwin (1957), studying gain in weight of brook trout at five temperatures, shows fastest growth at 55.4° F. and slowest growth at 69.8° F. Graham (1948) found that activity of brook trout decreased rapidly above 68° F. A change in environment that removes trout from their optimum

³ Webster, D. A. (1956) Fishery management report for 1955. Adirondack League Club, 26 (Multi.).

⁴ Fry, F. E. J. (1951) Some environmental relations of the speckled trout (*Salvelinus fontinalis*). Report from Proc. N. E. Atlantic Fish. Conf., 29 (Mimeo.).

growth range could cause a change in growth that might be reflected in the scales as a check. Summer surface temperatures generally exceed the optimum range in all four lakes. Lower Sylvan Pond and Panther Lake remain isothermous throughout summer, and water temperatures exceed 70° F. for long periods during most summers and occasionally approach 80° F. The waterway between Upper and Lower Sylvan Pond is warm (usually only 2 degrees cooler than Lower Sylvan Pond) and is inhabited by only a few fingerling trout. The outlet of Lower Sylvan Pond is cooled by several springs that enter at some distance below the pond. This stream supports a substantial population of fingerling trout with a limited food supply and their growth is rapid. Since a thermal block of warm water exists between the fingerling population and the lake environment during summer, fingerling trout (whether stocked as advanced fry or produced naturally) in Lower Sylvan Pond have two possible environments during the first summer.

There are two periods of optimum growth temperature during late spring and early autumn for fingerlings that remain in the stream. Between these two periods is an interval of summer temperatures above the range of optimum growth. These changes would be reflected on scales as a check between two periods of rapid growth. Cooper (1951) mentions formation of a similar false annulus in brook trout in a few Michigan streams after midsummer rise in water temperature. Trout spending their first summer in the outlet to Lower Sylvan Pond and migrating upstream in early autumn as the lake temperature drops (immigration which has not been established) would be likely to show a check resulting from increased growth in the richer lake environment. The production of such a mark "stocking check" resulting from a rapid increase in growth following release which is more prominent than the true annulus (it follows) has been established in all plantings of fin-clipped fall fingerlings made in these ponds.

Panther Lake has no tributaries or outlet utilized by fingerling trout. The outlet is warm, and a small cold spring entering the stream is inhabited only by advanced fry. Stocked fry or naturally produced trout in Panther Lake may also show a check suspected to be a false annulus resulting from midsummer increase in growth rate because there are higher temperatures. The strong check noted

on scales of Panther Lake trout following the hot summer of 1955 is an example.

A different explanation must be sought for the formation of checks in scales of trout from East Lake and Upper Sylvan Pond. Both of these lakes provide cool water in the hypolimnion which is available for summer retreat of trout when surface temperatures become too high. East Lake also has two spring-fed tributaries that remain in the optimal temperature zone of growth. Large numbers of advanced fry planted in East Lake in 1955 are known to have ascended the cool tributaries during the first warm period of early summer. Food supply in these tributaries was probably insufficient to support maximum growth rate in a large fingerling population. Similar conditions exist in the lake outlet. Trout of this planting that returned to the lake in late summer and early fall would probably show an increase in growth (Figure 3A) on returning to a habitat in which temperature and food supply favored optimum growth rate. Fish that did not pass downstream until spring 1956 would show no sharp change in growth during the first year (Figure 3B). A similar sequence of events could apply to naturally spawned members of the 1956 year class hatched in the stream system of East Lake. Trout of this year class that move downstream into the lake early in the first year would show two periods of rapid growth (spring and fall), while those that remain in the stream until late fall or the second spring would show only one period of rapid growth (first spring).

There are no data available from this study to describe the effect of vertical descent into deeper and cooler waters in the thermally stratified lakes (East Lake and Upper Sylvan Pond). Scales with no false annuli and with the first annulus well out from the focus presumably represent a life-history pattern of continuous lake growth. Some trout from Upper Sylvan Pond that show an accessory check may be immigrants from Lower Sylvan Pond. Tagging studies have established the fact that some mixing of populations takes place between the two ponds, but this mixing is probably not sufficiently great to account for all the false annuli observed in Upper Sylvan Pond trout scales.

High incidence of false annuli formed during the first year of life in the four populations studied has led to some doubt concerning procedures used in aging similar popula-

tions in nearby waters. Brook trout populations naturally produced or resulting from plantings of advanced fry must be carefully studied before any scale patterns are accepted as valid annuli.

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Atlantic Coast Migration of Large Striped Bass as Evidenced by Fisheries and Tagging

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ABSTRACT

During studies of Atlantic coast striped bass, *Morone saxatilis* (Walbaum), by the U. S. Fish and Wildlife Service and co-operators from 1955 to 1959, 478 large fish ranging in weight from 6 to 54 pounds and in age from 3 to 18 years were tagged. Tagging locations were the North Carolina coast, where 81 fish were tagged; Albemarle Sound and Roanoke River, North Carolina, where 97 fish were tagged; and Chesapeake Bay and tributaries, where 300 tags were applied. Catches by commercial and sport fisheries indicated that large striped bass concentrated on the coast of North Carolina in late fall and winter, on or near spawning areas for striped bass in North Carolina and Chesapeake Bay in late winter and spring, and along the coast north of Chesapeake Bay as far as Massachusetts in the summer and fall. Recaptures were made of 19 fish tagged on the North Carolina coast; 23 tagged in Albemarle Sound and the Roanoke River, North Carolina; 27 tagged in Chesapeake Bay and its tributaries; and 1 tagged in the Thames River, Connecticut. Some fish were recaptured near the tagging location but most of them migrated along the coast and were caught in other concentration areas during the season of greatest fishing pressure.

INTRODUCTION

In 1955 the U. S. Fish and Wildlife Service began a study which was concerned primarily with the effect of pollution, dams, and fishing pressure upon population size and spawning potential of striped bass, *Morone saxatilis* (Walbaum). Investigations were first centered in North Carolina and then extended to Chesapeake Bay in 1957 in co-operation with the States of Maryland and Virginia (Sykes, 1958).

One phase of the research was designed to determine the extent of movement of large striped bass prior to and following their appearance among populations of smaller fish of the same species in sound and bay systems along the Atlantic coast. Fish 6 pounds in weight and heavier were considered large. These usually occur in small numbers in commercial catches and display migratory habits which have not been adequately delineated.

Tagging of some large individuals was reported by Merriman (1941); Vladykov and Wallace (1952); and Raney, Woolcott, and Manning (1954). These studies resulted either in no recaptures or in recovery of the tagged fish near the site of release after a short period of time. Migration studies of large striped bass in Oregon (Morgan and Gerlach, 1950) and in California (Calhoun, 1952) show pre- and post-spawning movements within the rivers and bays, but no oceanic migration is indicated.

The present report describes migratory habits of large striped bass as determined by

recent tagging programs and examination of fisheries in North Carolina, Chesapeake Bay and its tributaries, and in Connecticut. The North Carolina coastal fishery is unique in that it is entirely dependent upon the capture of large striped bass which are concentrated by area and by season each year when virtually no other species are landed. This fishery is therefore treated in greater detail than those in other areas.

FISHERIES CATCHING LARGE STRIPED BASS

North Carolina

The only known commercial fishery now being operated exclusively for catching large striped bass on the entire Atlantic coast is a haul-seine fishery in North Carolina. It is centered on the outer banks between Kitty Hawk and Cape Hatteras, a distance of approximately 50 miles, and is active during the late fall and winter months. Fish landed by the seines are known in this area as "jumbo rock." The seines currently being used vary in dimension, but generally are 5 to 7 yards deep and 425 yards long. Size of mesh (stretched) varies from 6 to 8 inches at the end of the seine and 2 to 3 inches in the center.

The first known reference to the striped bass fishery on the outer banks was by Worth (1889). He reported a single catch made by haul seine in 1887 consisting of 4,000 pounds of striped bass ranging in weight from 5 to 60 pounds. Although catch records are not available for the years prior to 1956, this reference and recent interviews with fishermen of the

TABLE 1.—Monthly catches (pounds) of large striped bass landed on the North Carolina coast and Albemarle Sound for seasons 1956-57 through 1958-59¹

Month	Season					
	1956-57		1957-58		1958-59	
	Albemarle Sound	North Carolina coast	Albemarle Sound	North Carolina coast	Albemarle Sound	North Carolina coast
September	56	—	—	—	—	—
October	13	—	—	—	—	1,000
November	22	23,000	9	—	9	3,000
December	17	111,000	16	5,000	221	51,000
January	250	14,000	227	10,000	360	20,000
February	155	6,000	145	14,000	30	60,000
March	61	3,000	149	—	114	15,000
April	114	—	—	—	190	—
Total pounds	688	157,000	546	29,000	924	150,000

¹Unpublished catch data, U. S. Bureau of Commercial Fisheries, Biological Laboratory, Beaufort, North Carolina. Coastal catches were reported by fishermen to the nearest thousand pounds.

area indicate that this fishery has probably operated since 1887.

Catch records of the North Carolina coastal fishery were obtained for the fishing seasons 1956-57, 1957-58, and 1958-59. Of the three seasons, the first and third produced approximately equal catches of striped bass, while the 1957-58 production was comparatively low (Table 1). Wind and high seas limited passage of fishing boats through the surf during most of this season. A minimum of five and a maximum of ten seines were known to operate during the 3 years of observation, and the period of fishing extended from late November until early March.

In addition to the coastal landings, large striped bass are taken in small quantity in the fisheries of Albemarle Sound and the Roanoke River, North Carolina. Goode (1903) stated that numerous catches were made in the western end of Albemarle Sound in 1844. He further reported that in 1876 one seine haul took 320 striped bass weighing 37,000 pounds. Of this catch, 365 fish averaged 65 pounds per fish, and a few individuals weighed 90 pounds. Smith (1907) reported that large individuals were caught in the eastern end of the sound in 1891. Presumably small striped bass were also caught during these hauls, since a resident population of fish which are predominantly small presently inhabits the sound.

Examination of commercial striped bass catches in Albemarle Sound in the years 1956 through 1958 has shown that few large fish are caught there now. The few that were taken (Table 1) were caught by anchor gill nets, haul seines, pound nets, and purse nets. These types of gear are fished for small striped bass and American shad (*Alosa sapidissima*) and are distributed throughout the sound. Catches

on the coast and in Albemarle Sound landed in approximately the same season. Oregon Inlet, a cut in the outer banks between the Atlantic Ocean and Albemarle Sound, provides a passageway through which fish may move between the two fishing grounds.

The Roanoke River, a tributary of Albemarle Sound, is the principal striped bass spawning area in North Carolina. Wood (1884, 1910) stated that many large fish were caught and stripped of ova in that river during early attempts at artificial propagation, but few are now taken in the spawning run (Denson, 1958). There is no other known area in North Carolina where many of them are found in the spawning run, so no shift from one location to another is in evidence. Several striped bass weighing from 20 to 40 pounds have been reported in the Roanoke River in recent years, but a majority of them have weighed less than 6 pounds. Sykes and Lewis showed that spawning in the Roanoke River occurs primarily in late April and in May.¹

Chesapeake Bay

It was not possible to separate catches of large fish from the total striped bass caught in Chesapeake Bay because there is no separate large-fish fishery, and fish sizes in commercial catches were not obtained during this study. Some large fish were known to be present, however, particularly in spring during the spawning season. Spawning in Chesapeake Bay tributaries occurs from April through

¹ Sykes, James E., and Robert M. Lewis. Manuscript. Striped bass spawning populations in relation to changing environmental factors in Roanoke River, North Carolina.

TABLE 2.—Weight (pounds) and length (inches) of 265 large striped bass from North Carolina coast, Albemarle Sound, and the Roanoke River, and 303 large striped bass from Chesapeake Bay and the Potomac River

Location and year	Number of fish	Weight		Fork length	
		Range	Mean	Range	Mean
North Carolina					
1955 Coast	81	21.0–52.0	37.0	31.0–47.5	41.8
Albemarle Sound	3	6.0– 8.5	6.8	21.9–25.8	23.9
1956 Coast	22	*6.0–40.0	*27.0	21.5–45.0	37.4
Albemarle Sound	4	6.5– 7.9	7.4	23.3–24.9	24.1
Roanoke River	27	6.0–18.5	8.9	21.5–32.0	24.9
1957 Coast	2	**	**	41.0–45.0	43.0
Albemarle Sound	6	6.1–12.5	8.6	22.7–28.1	25.0
Roanoke River	19	6.0–14.2	8.4	20.4–29.2	24.0
1958 Coast	63	12.2–50.0	32.4	30.8–48.8	39.9
Albemarle Sound	21	6.2–16.2	8.4	20.2–31.6	24.6
Roanoke River	17	6.2–10.0	7.4	20.3–24.6	22.6
Chesapeake Bay area					
1957 Chesapeake Bay	112	6.0–44.0	12.6	21.0–44.0	29.6
1958 Chesapeake Bay	9	7.0–51.6	26.6	25.0–46.6	35.3
1959 Chesapeake Bay	28	†	†	21.0–50.0	30.2
Potomac River	154	6.0–57.0	16.2	21.7–46.6	30.1

*Estimated
 †No range; each of two fish estimated at 35 pounds
 ‡Only one fish weighed (16.5 pounds)

(Massmann *et al.*;² Pearson, 1938; Tres-
 1952). Recent studies have indicated that
 spawning in the Potomac River in 1959
 completed by May 15.

North of Chesapeake Bay

Commercial striped bass fishing is illegal
 in states north of Chesapeake Bay with the
 exception of Delaware, New York, and Rhode
 Island. There are sport fisheries in several
 states, and the principal areas where the large
 striped bass are caught are on the ocean shores
 of these states. The most productive areas on the
 basis of hook-and-line catches are: Barnegat
 Bay and Sandy Hook, New Jersey; Montauk
 Point, New York; Block Island, Narragansett,
 Rhode Island; and Newport, Rhode Island; and
 Nantucket, Nantucket, and Cape Cod, Mass-
 achusetts (Fitzpatrick and Cookson;³ Lyman
 and Woolner, 1954). In some of these states
 the catches can be marketed. Casting and
 trolling are both practiced in the coastal sport
 fishery, which is usually active from early
 spring through late October.

Massmann, William H., Ernest C. Ladd, and
 N. McCutcheon. (1952) A biological survey of
 the Potomac River, Virginia, Part 1. Virginia
 Game and Inland Fisheries Lab., Gloucester Point, 112 pp. (Mimeo.)
 Summaries of reports on striped bass investiga-
 tions for 1956 and 1957. Commonwealth of Mass-
 achusetts, Dingell-Johnson Proj. F4R. (Mimeo.)

MATERIALS AND METHODS

Four types of tags were used to mark the
 fish in this study. Petersen disk tags with
 nickel pins were used on the fish tagged on
 the North Carolina coast. Petersen disk, nylon
 streamer, and soft and hard spaghetti tags
 were used in Albemarle Sound and in the
 Roanoke River (Davis, 1959). In the Ches-
 apeake Bay area, Petersen disk, nylon streamer,
 and jaw ring tags were used. The jaw ring, or
 split ring and plate tag, was designed and
 described by Vladykov (1956). A return
 address and serial number were printed on
 each tag, and a reward was paid for the tag
 return.

Scales were collected and fork length and
 weight were recorded from portions of com-
 mercial landings and from most of the fish
 which were tagged. Weights of some fish
 tagged on the North Carolina coast in 1956
 and 1957 were estimated. To check the ac-
 curacy of the estimates, they were plotted on
 the empirical length-weight curve of North
 Carolina fish from which complete data
 were obtained. Comparison showed estimated
 weights to be within the observed ranges for
 fish of similar lengths.

Large fish on North Carolina beaches were
 immobilized for marking by having one
 operator hold the tail down while another
 straddled the head region and faced the tail

TABLE 3.—Age of 414 large striped bass from commercial catches in North Carolina and the Potomac River

Age group	North Carolina coast				Albemarle Sound				Roanoke River			Potomac River	Total
	1955	1956	1957	1958	1955	1956	1957	1958	1956	1957	1958	1959	
III	—	—	—	—	1	—	—	1	1	2	1	18	
IV	—	1	—	—	1	—	1	4	2	6	8	25	
V	—	—	—	2	—	2	1	5	13	4	4	14	
VI	1	2	—	2	1	—	3	7	7	2	4	25	
VII	—	2	—	13	—	—	—	2	—	—	—	28	
VIII	3	4	—	6	—	1	1	—	2	2	—	22	
IX	4	2	—	6	—	—	—	—	1	—	—	10	
X	3	1	—	6	—	—	—	—	—	—	—	6	
XI	5	4	—	4	—	—	—	—	—	—	—	3	
XII	3	2	1	8	—	—	—	—	—	—	—	3	
XIII	11	—	1	5	—	—	—	—	—	—	—	1	
XIV	14	2	—	6	—	—	—	—	—	—	—	5	
XV	16	1	—	3	—	—	—	—	—	—	—	2	
XVI	7	—	—	2	—	—	—	—	—	—	—	—	
XVII	5	—	—	—	—	—	—	—	—	—	—	—	
XVIII	1	—	—	—	—	—	—	—	—	—	—	1	
Number	73	21	2	63	3	3	6	19	26	16	17	165	4
Average age	13.4	9.6	12.5	10.2	4.3	6.0	5.8	5.3	5.5	4.9	4.6	6.8	8

to attach the tag. Scales were taken and length was measured while the fish was lying on the beach. For determination of weight, the fish was pushed head first into a large plastic bucket which was then suspended from scales mounted on a tripod. Immediately after weighing, the fish was carried in the bucket to the water.

In Chesapeake Bay and tributaries fish were tagged and scales, length, and weight obtained as they were taken from nets into commercial fishing boats. Tagging was done in the manner previously described, but was slightly more difficult because deck space was limited.

Twenty-two large striped bass were tagged in the vicinity of Oregon Inlet, North Carolina, in December 1956, and 57 were tagged there in December 1958. Because fishing success was relatively poor there in the 1957–58 season, few fish were observed and only two were tagged.

From 1955 through 1958, 4,361 striped bass of all sizes were tagged from commercial fishing gear in Albemarle Sound, North Carolina. Of these, 34 fish were in the large category and were tagged from late October through March. From 1956 through 1958, 856 fish of all sizes including 63 large fish were tagged from commercial gear in the Roanoke River, North Carolina. The period of tagging extended from April through early July.

During the cooperative study between the States of Maryland and Virginia, and the U. S. Bureau of Commercial Fisheries, 7,254 fish were tagged in Chesapeake Bay and tributaries from 1957 through 1959, and of these 149 were large fish. Areas of tagging in

Virginia were the York, James, and Rappahannock Rivers; and in Maryland, the Neck and Elk Rivers, the Chesapeake and Delaware Canal, and Spesutie Island, St. Point Bar and in the vicinity of the Little Choptank River.⁴ In addition to this tagging in the Chesapeake Bay system, 2,197 striped bass of all sizes taken by commercial gear were tagged in the Potomac River from January to May, 1959. Of these, 92 were large fish.

In the spring and summer of 1956, 200 striped bass of all sizes were tagged in the Thames River, Connecticut, by the Connecticut State Board of Fisheries and Game. Weights at the time of tagging are unknown except for one large fish.

In addition to those fish tagged, large striped bass landed by beach seines and other commercial fishing gear were occasionally examined. In December 1955 and December 1958, a total of 87 large striped bass were examined on the North Carolina coast and length, weight, and scales were obtained for the purpose of supplementing data for tagged fish. In 1959, 62 large fish were examined from catches in the Potomac River.

Ages were determined from plastic impressions of scales which were removed from the left side of the body midway between the dorsal fins and the lateral line. Usually 1

⁴ Information regarding these fish and some taken in the Chesapeake Bay area in 1955 and 1956 prior to the co-operative study was supplied through the courtesy of Maryland Department of Research and Education, Maryland Department of Tidewater Fisheries, D-J Project F3R—Rockfish Investigations, and Virginia Fisheries Laboratory.

Table 4.—Summary of 19 striped bass tagged in 1956 and 1958 on the North Carolina coast and recaptured

Date of tagging	Number tagged	Location of recovery							
		Near tagging site		Albemarle Sound ¹		Chesapeake Bay ¹		On coast north of bay ²	
		Number	Weight	Number	Weight	Number	Weight	Number	Weight
October 3–19, 1956	22	—	—	2	25.0 ³	2	40.0 ³	2	25.0 ³
October 2–23, 1958	57	5	29.2	—	6.0	6	30.0 ³	2	10.0 ³
			19.5				49.5		33.0
			17.8				34.2		27.2
			17.8				32.8		
			17.2				30.2		
							29.1		
							18.2		
	79	5	—	2	—	8	—	4	—

¹ Prior to and during spawning season
² After spawning season
³ Estimated weight

Scales were obtained from each fish. The scale impressions were viewed with an Eberbach scale projector and a dissecting microscope, and age assigned from the number of completed annuli. Two biologists read the scales independently and in cases of disagreement the scales were re-examined jointly. The joint reading produced agreement in two-thirds of the cases.

Lengths and means in weight and fork length were obtained from 568 large striped bass collected and examined in North Carolina and the Chesapeake Bay area from 1955 to 1959 (Table 2). Age frequency of 414 North Carolina and Potomac River fish is shown in Table 3.

TAG RECOVERIES

Of the 79 large fish tagged on the North Carolina coast in 1956 and 1958, recoveries were made in four separate fishing areas: five within 10 days after release near the point of tagging; two in Albemarle Sound prior to the spawning season; eight in the Chesapeake Bay system prior to and during spawning season; and four on the Atlantic coast after the spawning season (Figure 1). One of these four fish was taken off Sandy Hook, New Jersey, on June 16; one at Elberon, New Jersey, on August 5; one off Watch Hill, North Carolina, on July 15; and one at Provincetown, Massachusetts, on September 27 (Table 4). Neither of the two fish tagged in 1957 was recaptured.

Of the 34 large striped bass tagged in Albemarle Sound in 1955, 1956, 1957, and 1958, one was recovered at Dennis, Massachusetts, on July 8, 1956; 12 in the sound during commercial fishing seasons; and one in the Roanoke River in May (Table 5).

Of the 63 large fish tagged in the Roanoke River during the spawning runs of 1956, 1957, and 1958, one was recovered near the tagging site in the season of tagging and eight in Albemarle Sound during commercial fishing seasons of the next 2 years (Table 5).

Of the fish tagged in the Chesapeake Bay area, 14 recoveries were made from the 92 large fish tagged on and near the spawning

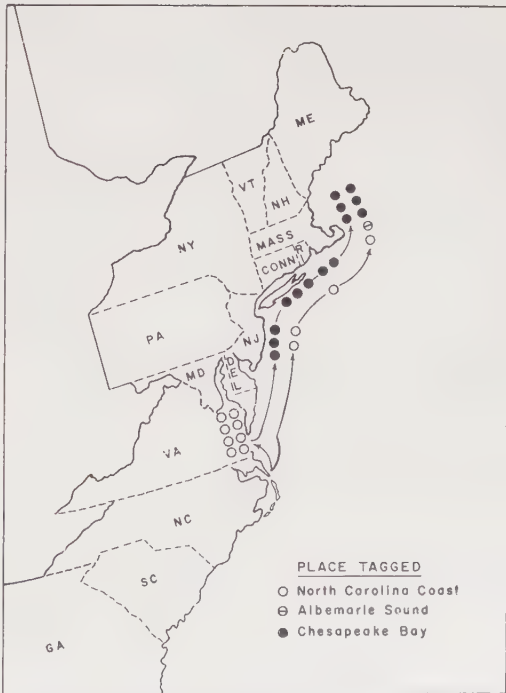


FIGURE 1.—Recovery points of fish tagged on the coast of North Carolina; in Albemarle Sound, North Carolina; and in Chesapeake Bay.

TABLE 5.—Summary of 23 striped bass tagged in Albemarle Sound and in the Roanoke River, North Carolina, 1955–58, and recaptured

Date and place of tagging	Number tagged	Location of recovery							
		Near tagging site		Albemarle Sound ¹		Roanoke River ¹		On coast north of bay ²	
		Number	Weight	Number	Weight	Number	Weight	Number	Weight
Albemarle Sound									
November 22–28, 1955	3	—	—	—	—	—	—	1	8
November 13—									
December 10, 1956	4	1	6.5	—	—	1	7.6	—	—
February 25–27, 1957	5	—	—	4	9.0	—	—	—	—
					7.8				
					7.6				
					6.1				
October 29, 1957	1	—	—	1	8.5	—	—	—	—
January 15—									
March 24, 1958	21	3	10.8	3	16.2	—	—	—	—
			7.4		10.1				
			6.2		8.2				
Roanoke River									
April 19—July 2, 1956	27	—	—	6	17.0	—	—	—	—
					9.0				
					7.0				
					6.3				
					6.2				
					6.0				
April 1—May 14, 1957	19	1	8.3	1	6.5	—	—	—	—
April 30—May 9, 1958	17	—	—	1	6.2	—	—	—	—
Total	97	5	—	16	—	1	—	1	—

¹Prior to or during spawning²After spawning

grounds of the Potomac River in 1959 (Table 6). Four of these fish were recovered in the Potomac River and eight in Chesapeake Bay during the spring and summer of 1959. Two fish were caught on the coast north of the bay subsequent to the spawning season; one at Cuttyhunk, Massachusetts, on June 10, and the other at Montauk, New York, on October 17.

The 13 returns from fish tagged in other areas of Chesapeake Bay were made after the spawning season. Recovery of 12 of these fish was made along the Atlantic coast north of the bay (Figure 1) from June through October, and one fish was recovered south of the bay on the North Carolina coast in December. Some recoveries referred to have been listed previously by Mansueti (1958), by Hollis for the Maryland Board of Natural Resources (1955, 1956, 1957, and 1958), and by Hollis and Davis.⁵ These include the recovery of fish tagged in the Nanticoke River, in the Chesapeake and Delaware Canal, and at Spesutie Island (Table 6).

One fish which was tagged in the Thames River, Connecticut, in June 1956 was recaptured in December 1959, 891 days later,

on the North Carolina coast. This was the only fish recovered in North Carolina of the 131 fish tagged in Connecticut. Twenty-three recoveries were made either in the Thames River or nearby water systems in the next 3 years. An additional three fish were recovered along the Atlantic coast south of the tagging site; one off New Jersey and two in Chesapeake Bay. Weights of the recaptured fish are unknown except for the fish recovered in North Carolina.

DISCUSSION AND CONCLUSIONS

It is apparent from the present study and those made by Merriman (1941), Rarick (1952), and Vladykov and Wallace (1952) that two primary size groups of striped bass exist in fisheries of the Atlantic coast; one occurring prominently in the 2- to 3-pound class and the other in the 30- to 40-pound class. The smaller group ranges in weight from 2 to 6 pounds and the larger from 6 pounds to approximately 75 pounds. The latter group, which comprises a small portion of the total catch, represents the small percentage of fish which escape natural and fishing mortality for several years. Fishing mortality appears to be particularly high during the first 3 years of life.

The separation of the two groups is most apparent in North Carolina, where in December both a geographical and a size difference

⁵ Hollis, Edgar H., and Harold A. Davis, Jr. (1955) Report of striped bass studies in Maryland. Atlantic States Marine Fish. Comm., Chesapeake Bay Sect., 14th Ann. Meeting, Virginia Beach, Va., Appendix C.B. (Mimeo.)

TABLE 6.—Summary of 27 recaptured striped bass tagged in Chesapeake Bay area

Place of tagging	Date of tagging	Number tagged	Location of recovery					
			Near tagging site (within bay system)		On coast north of bay after spawning		On coast south of bay after spawning	
			Number	Weight	Number	Weight	Number	Weight
Potomac River, Maryland	April 22, 1955	4	—	—	1	27.0	—	—
	May 9–10, 1956	15	—	—	1	15.0 ¹	—	—
	April 19–29, 1958	2	—	—	2	48.0	—	—
	April 9, 1959	5	—	—	1	16.0	—	—
Pentac Island, Maryland	May 10, 1956	34	—	—	3	20.0 ¹	—	—
						25.0 ¹		
						24.0 ¹		
						22.5 ¹		
Chesapeake and Delaware Canal, Maryland	April 26–30, 1957	16	—	—	1	6.5	1	45.0 ²
Potomac River, Maryland	January 24—May 4, 1959	92	12	17.2 16.0 15.2 15.0 14.9 14.8 13.6 13.5 12.3 12.0 11.9 8.8	2	28.5 21.5	—	—
Roanoke River, Virginia	February 27, 1957	37	—	—	2	11.2 8.6	—	—
	February 25, 1958	1	—	—	1	7.5	—	—
Total		206	12	—	14	—	1	—

¹Weight determined at time of recovery
²Estimated weight at tagging

clearly illustrated. On the Albemarle and side of the outer banks there is an extensive, resident population of the small size group, while on the ocean side fish in the large group are concentrated. Most fish from coastal catches weighed 6 pounds or more, and the population was distinct from all others on the basis of fish size and location of the group in the season of observation.

The recovery of large striped bass tagged in the North Carolina coastal fishery, which is specifically for large fish, showed that this fishery is seasonal, because large fish are present for only short periods during their extensive coastal movements. Fish tagged on the coast of North Carolina in two fishing seasons were recovered in the commercial fisheries of North Carolina or Chesapeake Bay prior to or during the spawning period or by sport fisheries on the coast north of Chesapeake Bay after the spawning season. Some of the spring recoveries were made directly on the near the spawning grounds of Chesapeake Bay and Albemarle Sound tributaries. These recoveries link the North Carolina fish with large striped bass that are taken occasionally on known spawning grounds of Chesapeake Bay and Albemarle Sound. Fish tagged in

Albemarle Sound and in the Roanoke River over a 4-year period were recovered either in the commercial fisheries of the sound or river or in the sport fisheries north of Chesapeake Bay after the spawning season.

The combined tag returns from all areas show a continuation of what is believed to be a seasonal migratory cycle similar to that of the American shad (Talbot and Sykes, 1958). Tags applied to striped bass in the bay and tributaries over a 5-year period were recovered from the bay or from the Middle Atlantic and New England coasts in the summer and fall and on the coast of North Carolina in late fall and winter.

The fact that some fish tagged in the Potomac River were recovered in Chesapeake Bay as late as September shows that all of the large fish do not leave the bay immediately after the spawning season. Fish tagged in Albemarle Sound and in the Roanoke River over a 4-year period were recovered as late as October in the sound and did not all leave it immediately after the spawning season. A few large striped bass are taken at all seasons of the year in Albemarle Sound and Chesapeake Bay, but these fish appear in largest number at the times and in the places of

major tag recoveries. Movement from New England south to North Carolina needs further verification even though a complete migratory cycle is suggested.

This study of movement of large striped bass between states helps in clarifying one element of the life history of this species and presents problems differing from those encountered in management of the more restricted estuarine populations. It is apparent that the large fish are subject to exploitation in three widely separated geographical areas each year. With this knowledge available, further study of management problems will be facilitated.

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Swimming Speed of Immature Atlantic Herring with Reference to the Passamaquoddy Tidal Project¹

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ABSTRACT

To predict possible effects of the dams and gates of the proposed Passamaquoddy Tidal Power Project on herring movement in and out of the Passamaquoddy Bay region, information was first needed on the swimming performance of the fish. Maximum and sustained swimming speed tests designed for this purpose indicated (1) that the maximum swimming speed for herring 60 to 219 millimeters long ranged from 2.3 to 4.4 feet per second, and (2) that the swimming endurance (length of time a fish was able to swim in a particular water velocity) for herring of similar lengths exposed to water velocities of 1.2 to 3.2 feet per second ranged from 1 to 115 minutes. If the fish responds in the field as in the laboratory, the filling gates that operate at flood tide and emptying gates that operate at ebb tide would not appear to prevent migration.

INTRODUCTION

In the early fall of 1956 an investigation was run to determine the possible effects the construction of dams in the Passamaquoddy region, New Brunswick, Canada, would have upon the fisheries in the area. Of primary importance are the immature Atlantic herring (*Clupea harengus harengus* Linnaeus) which comprise approximately 85 percent of the total fish landings. Returns from 1957 and 1958 taggings suggest that these herring move in and out of Passamaquoddy Bay through either Letite or Western Passage, areas in which the surface water currents at times may reach a velocity of 10.0 feet per second (McIntyre and Skud, 1958; Skud and Boyar, 1958). With the possibility of even stronger currents being produced if the proposed Passamaquoddy Tidal Power Project dam and gates are constructed (Trites, personal correspondence), information was needed about the response of herring to currents of different velocities. To provide this information, studies of maximum and sustained swimming speed of immature herring were made at the Bureau of Commercial Fisheries Biological Laboratory, Boothbay Harbor, Maine. The maximum swimming speed study was concerned with the ability of a fish to maintain a position or actually swim against known water velocities over a 30-second period; the endurance study, with the length of time a fish could swim against a specific water velocity.

There is considerable published information on swimming speeds of fish. Many data have been obtained by timing fish movements in

aquaria (Regnard, 1893), fishways (Stringham, 1924; R. L. Dow, personal correspondence), tanks (Lane, 1941), ponds (Davidson, 1949), culverts (Wales, 1950), and artificial channels (Ohlmer and Schwartzkopff, 1959). Recently, values for swimming speeds have been obtained principally by the use of a longitudinal, fixed trough (Kerr, 1953; Fields *et al.*, 1954²; Blaxter and Dickson, 1959) and by a circular, rotating trough (Fry and Hart, 1948; Radcliffe, 1950; Gray, 1957; Brett *et al.*, 1958; and Bainbridge, 1958). In the former, fish are subjected to different velocities of inflowing water against which they may or may not maintain their positions. In the circular, rotating trough (popularly known as the "fish wheel"), the water may be moved at varying speeds relative to the fish's visual field. In the present study, an attempt has been made to relate data on swimming speed from fish wheel experiments with field conditions.

MATERIALS AND METHODS

A circular tank (Figure 1), modified after Fry and Hart (1948) and Bainbridge and Brown (1958), was built to contain a trough with an outside diameter of 35¾ inches, a cross section of 5½ inches, and a depth of 6 inches. A 1-horse-power variable speed-reducer motor linked by a two-pulley belt system rotated the tank, and a graduated hand-wheel control varied the speed. Preliminary tests indicated that the apparatus could pro-

² Fields, P. E., R. J. Adkins, and G. L. Finger. (1954) The swimming ability of immature silver salmon (*Oncorhynchus kisutch*) measured in an experimental flume. Univ. of Wash., School of Fish., Tech. Rept. 9, 22 pp. (Mimeo.)

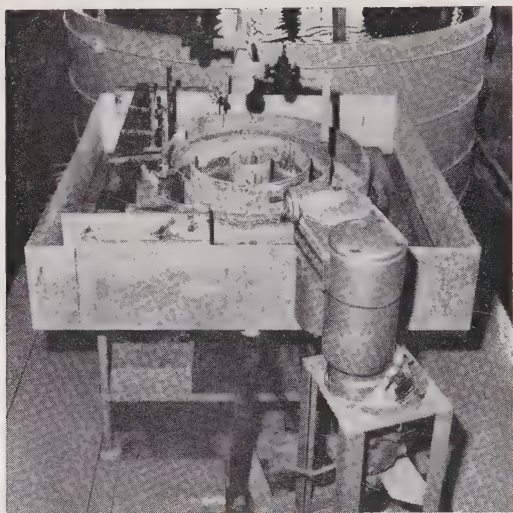


FIGURE 1.—Circular tank used in the swimming studies.

duce water velocities as high as 11 feet per second. Overhead jets supplied water to the trough; the rotation of the trough and a $\frac{1}{4}$ -inch drain eliminated excess water.

Fish to be tested were placed in a specially designed stationary cage (25 inches long by $3\frac{3}{4}$ inches wide by 7 inches high, Figure 1) with wire mesh ends located in a section of the rotating trough. The cage permitted excellent observation of the fish's behavior and also eliminated visual reference points of the trough. A specially designed current meter (Boyar and Schueler, 1960) measured the water velocity in the cage.

Two types of experiments were conducted: (1) maximum swimming speed studies and (2) sustained swimming speed (endurance) studies. The maximum swimming speed was considered equivalent to the water velocity beyond which no individual could maintain its position for more than 30 seconds. The length of time a fish was able to maintain its position in a particular water velocity was considered its sustained swimming speed. In the first test, fish in the cage were subjected to a water velocity in which they swam steadily. The water velocity was then increased gradually. When the fish was pinned against the rear screen of the cage, its maximum swimming speed was considered to be reached. In the endurance studies, fish were subjected to specific water velocities and made to maintain their position until pinned against the cage's rear screen. On occasion, a gentle prod with a glass rod induced the fish to leave the screen

and swim forward. If the fish failed to leave the screen after 15 seconds, the test was considered completed.

Herring to be tested were held in a live-aquarium (Boyar and Sindermann, 1959), and appeared to be in good condition, differing in weight from wild fish of equivalent length by no more than 1 gram. Fish from 60 to 219 millimeters long, weighing from 2 to 65 grams, were used. Temperatures during the maximum swimming speed studies were from 1.4° to 5.6° C., and 9.5° to 11.2° C.; and in the sustained swimming speed studies from 1.4° to 5.6° C.

RESULTS

Rheotaxis tests

Circular tank experiments are conducted on the premise that fish provided with a fixed visual reference point will swim in a direction opposite to the movement of the tank, in a manner similar to their behavior in a stream. In a stream, the current tends to force the fish downstream, and in the tank, backward. In either case, the fish opposes the movement of water and swims, exerting enough energy to keep its same visual field. Lyon (1934) and Keenleyside and Hoar (1954) reported that when a fish swam against a current it did so in response to (1) visual, (2) tactile, or (3) labyrinthine reflexes. This assumption infers that the fish had to see or feel some fixed object in its environment, or somehow experience the currents over the bottom of the tank, before it would orient against the current.

Prior to making herring swimming speed studies, it was necessary to determine whether positive rheotaxis would occur in this species. One hundred and thirteen fish from 65 to 219 millimeters long were tested in water velocities ranging from 0.5 to 3.0 feet per second (Table 1). Since at the time of this study there is no published report of their responses to various water velocities, it was decided that they oriented opposite to the water flow. Within 20 seconds of exposure, the herring were positively rheotactic.

TABLE 1.—Percentage of herring oriented against the current at various water velocities at the end of 20 seconds.

Number of fish	Range of length (millimeters)	Water velocity in feet per second			
		<0.7	0.7	1.5	2.2
27	65–99	98	100	100	—
29	100–134	94	100	100	—
36	135–169	86	95	100	100
21	170–200	82	90	100	100

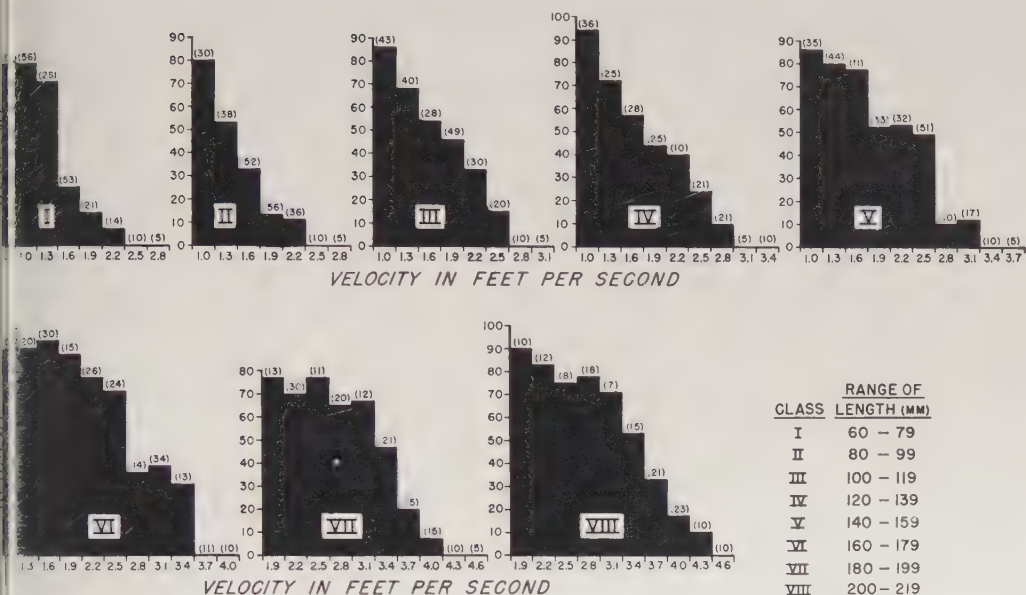


FIGURE 2.—Percentage of herring able to maintain position for 30 seconds against various water velocities (number of fish tested in parentheses).

Fish failed to respond positively only at speeds of 0.7 foot per second or less, and these were larger than 134 millimeters. The results indicated that herring, under the conditions of the experiment, will orient against various water movements, and that this response is dependent upon the fish's size and water velocity.

Maximum swimming speed tests

The results of maximum swimming speed tests with 1,551 herring from 60 to 219 millimeters long are shown in Figure 2. Fish have been divided into eight length classes, each with a range of 20 millimeters. The water velocities vary from 0.9 to 4.7 feet per second and the data have been grouped by 0.3-foot-per-second intervals.

There appears to be a direct relationship between swimming speed and body length of fish, *i.e.*, the longer the fish, the greater percentage of individuals able to swim at a particular current. In addition, there is indication that increase in water velocity resulted in a decrease in the percentage of fish of a particular class to swim at this velocity. Herring's maximum swimming speed was considered to be the maximum velocity at which fish could swim over a 30-second period. Because there were relatively few tests conducted at this limit, additional tests at the

next higher speed (increase of 0.3 foot per second) were made for all length classes and served as confirmation. The critical velocity has been arbitrarily designated as the water velocity at which 60 percent or more of the fish of a particular class were unable to swim. The maximum swimming speeds and the critical velocities are shown in Figure 2.

The difference between the maximum swimming speed and the mean critical velocity of any class ranged from 0.4 to 0.7 foot per second.

Sustained swimming speed tests

The swimming endurance of 215 herring from 68 to 205 millimeters long was determined for water velocities from 1.2 to 3.2 feet per second. The results obtained are shown in Table 2. Rectification of the non-linear data was found to depend on a log-log transformation and could be illustrated by a linear graph, log of endurance in minutes (E) plotted against log of length in millimeters (L). This indicates that endurance is a function of approximately the fourth power of length (Table 3, column 3). The length-endurance curves plotted from these calculated functions are shown in Figure 3, while the results of the linear regression analysis are shown in Table 3. K and i are the values for the slope and y -intercept of the regression line;

TABLE 2.—Relationship between length (L) in millimeters and actual endurance (E) in minutes of herring exposed to various water velocities

Water velocities in feet per second														
1.2		1.4		1.7		2.0		2.3		2.6		2.8		3.0
L	E	L	E	L	E	L	E	L	E	L	E	L	E	L
68	1	69	1	74	1	88	1	81	1	104	1	118	1	134
72	2	79	4	77	2	99	1	94	1	111	1	128	2	140
78	2	81	2	78	2	103	4	98	2	118	2	134	2	148
82	5	85	3	80	4	109	14	105	3	122	2	136	3	149
84	3	87	3	81	1	114	7	109	11	129	3	137	4	152
90	8	92	2	89	2	114	19	113	5	132	4	138	5	154
90	8	93	13	91	4	119	13	118	6	137	4	139	5	158
92	7	94	8	93	2	122	8	124	5	137	5	142	13	159
92	26	99	11	101	14	123	16	132	11	143	1	144	4	163
95	13	105	9	105	11	123	14	136	8	147	2	144	11	168
102	14	107	13	108	7	126	15	140	9	151	17	147	3	176
106	13	109	19	116	14	128	11	146	16	155	41	156	5	182
107	20	113	12	122	11	130	21	150	9	157	10	160	9	189
108	19	116	22	128	17	133	16	153	12	167	18	165	5	
111	18	118	17	132	20	137	10	155	16	168	14	172	3	
114	23	123	21	134	22	146	14	156	14	172	14	173	13	
131	32	127	19	137	18	147	28	159	19	172	16	174	4	
133	41	129	26	140	19	148	39	163	22	176	18	178	16	
139	40	132	23	142	54	149	19	168	29	179	24	184	9	
143	63	134	31	144	66	150	12	170	34	184	29	184	18	
152	82	137	48	145	42	151	14	174	38			188	14	
157	120	142	39	145	52	152	12	178	41			189	14	
		143	20	149	49	160	23							
		147	26	154	59	162	34							
		150	150	156	65	165	21							
		154	132	156	48	171	33							
				159	68	176	39							
				162	80	177	45							
				166	73									

n, the number of fish tested; S.E., the standard error of the estimate; *r*, the value of the correlation coefficient; and *t*, the variate testing significance of the slope. Significant values at the 1 percent level for *r* and *t* have been obtained for velocities of 1.2 to 2.8 feet per second. At a velocity of 3.0 no significant values for either *r* or *t* were obtained, while at a velocity of 3.2 a significant value for *t* and not *r* was obtained.

From the analysis it appears that the herring's swimming endurance is dependent upon its length and the water velocity. As the velocity increased, swimming endurance for

a particular length class decreased. As a fish's size increased, its swimming endurance at a particular water velocity increased.

The slopes for the swimming endurance of fish exposed to velocities of 1.4 and 1.7, 2.0 and 2.3, 2.6 and 2.8, and 3.0 and 3.2 are similar. The maximum difference of endurance between these curves was 15 minutes for fish tested in velocities of 1.4 and 1.7, 10 minutes for fish tested in velocities of 2.0 and 2.3, 6 minutes for fish tested in velocities of 2.6 and 2.8, and 4 minutes for fish tested in velocities of 3.0 and 3.2. Because of this similarity, the fish tested were regrouped into larger classes (Table 4).

TABLE 3.—Statistical analysis of the length-endurance relationship of herring exposed to various currents (*X* = log L, *Y* = log *E*)

Velocity (feet per second)	<i>n</i>	Regression line <i>Y</i> = <i>KX</i> + <i>i</i>	S.E.	<i>t</i>	
1.2	22	<i>Y</i> = 4.9825 <i>X</i> + (−8.9111)	0.1659	14.30*	0.9
1.4	26	<i>Y</i> = 4.3393 <i>X</i> + (−7.7063)	0.3285	6.82*	0.7
1.7	29	<i>Y</i> = 4.3269 <i>X</i> + (−7.8268)	0.2176	13.16*	0.8
2.0	28	<i>Y</i> = 4.1561 <i>X</i> + (−7.7131)	0.2343	7.23*	0.8
2.3	22	<i>Y</i> = 4.5268 <i>X</i> + (−8.6657)	0.4930	12.87*	0.9
2.6	20	<i>Y</i> = 4.7345 <i>X</i> + (−9.4505)	0.3712	4.56*	0.7
2.8	22	<i>Y</i> = 4.0135 <i>X</i> + (−8.0363)	0.2407	4.76*	0.7
3.0	13	<i>Y</i> = 2.4956 <i>X</i> + (−5.0697)	0.8276	1.43	0.3
3.2	16	<i>Y</i> = 4.2215 <i>X</i> + (−8.7879)	0.6347	5.17*	0.2

*Significant at the 1 percent level

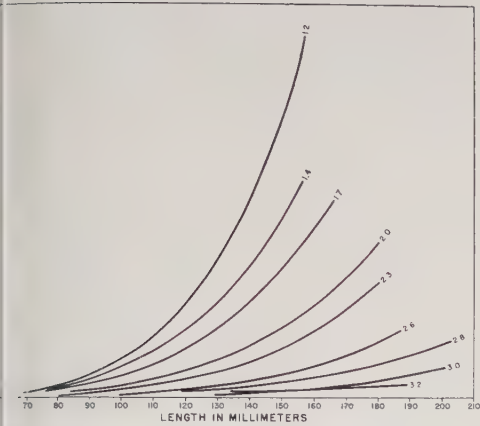


FIGURE 3.—Calculated length endurance relation- of herring exposed to various currents. (Figures extreme end of curves represent water velocity in per second.)

It can be seen in the table that only fish water than 139 millimeters would be able swim as long as 30 minutes; this would be possible only at velocities less than 2.0 feet second.

DISCUSSION

In recent years, water power developments ve been partially responsible for studies on swimming speed of fish. Of primary in- est have been the investigations concerned b. the ability of fish to swim through gates up proposed fishways. Most of the values ained have been for fresh-water or ana- omous fish. In a situation such as the Passamaquoddy Power Project, the marine n (in this case herring) are of primary ortance. Information on herring was ded to evaluate effects of proposed struc- es.

In the present study, the maximum swim- ing speed was found to range from 2.3 to feet per second for fish from 60 to 219 ilimeters. This range agrees quite closely h the 1.8 to 4.4 feet per second found by xter and Dickson (1959) for European rring of comparable length. The ratio of ximum speed to length ranged from 6 to 9, slightly less than the 10 proposed by Gray (1957) as a general ratio for the maximum ed of small fresh-water fish. The ability the fish to exert a sudden burst of speed e been postulated by Gray to be of more ortance than the maintenance of cruising ed. This assumption is undoubtedly true situations where a darting movement is ed to catch prey, escape predators, or for

TABLE 4.—Average swimming endurance of herring (in minutes) against various water velocities

Range of length (millimeters)	Water velocity in feet per second								
	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.0	3.2
<99- 99	6	4	3	2	1	0			
100-139	28	22	16	9	6	3	2	1	1
140-179	89	50	42	28	22	11	7	2	3
180-219						19	13	4	8

other reasons. The importance of this sudden burst of speed, however, is of less concern than cruising speed in a situation where fish must swim at a steady rate. Cruising speed has been defined by Fry and Hart (1948) as "that speed at which the fish could swim steadily for some period of time, although presumably after hours fatigue would set in." In the past, this method was satisfactory to obtain values for a fish's swimming performance at a particular current speed. In the present study, sustained speed (endurance) tests at a number of velocities were made and are proposed as the best means of obtaining endurance-length values. Herring exposed to water velocities of 1.2 to 3.2 feet per second gave endurance ranging from 1 to 115 minutes. The results of the tests appear to be the first complete series of this type. Although temperature would probably have an effect on swimming endurance, its effect was not tested in the present study.

If the proposed dams and gates are constructed across Passamaquoddy Bay, it is apparent that herring entering the bay through the passages could do so only at times when the filling gates were open. Since this period will be only 3 out of 12½ hours, the time of access to the bay by this route would be reduced considerably. If herring enter primarily at flood tide at present, no drastic reduction in fish immigration should occur if the dams and gates are constructed. The closure of the gates during ebb tide will prevent any fish's leaving the bay through the passage, while the flood tide would be too strong for it to swim against. As a result herring could enter but not leave the bay through the passage. The same conditions would also apply to Western Passage where the filling gates are designed to open and close at the same time as those of Letite Passage and where water velocities would be similar. Herring could enter but not leave.

The question remains as to whether herring could enter the bay region through the emptying gates. Since water velocity outward

through these would be approximately the same as that of the inflow through the filling gates (Trites, personal correspondence), any massive immigration would be unlikely. Although the emptying gates would be open $3\frac{1}{2}$ hours out of $12\frac{1}{2}$, fish entering the bay by this route could do so only when the water velocity was less than 2.0 feet per second, a period of less than 20 minutes every 24 hours.

ACKNOWLEDGMENTS

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Harvest, Age Structure, and Growth of Game Fish Populations from Priest and Upper Priest Lakes¹

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ABSTRACT

Priest and Upper Priest Lakes located in northern Idaho produced a catch of approximately 100,000 fish in 1956. The catch was composed of kokanee (93 percent), cutthroat trout (5 percent), and Dolly Varden and lake trout (2 percent). Three out of four fishermen were nonresidents, and a third of the hours fished were expended by anglers from more than 600 private cabins. The average rate of catch for kokanee was 2.5 fish per boat per hour on Priest Lake and 0.9 on Upper Priest Lake; for cutthroat trout it was 1.0 fish per boat per hour on the upper lake and 0.7 on Priest Lake. Juvenile cutthroat trout were found to spend 2 to 3 years in tributary streams before entering the lakes. The catch and spawning escapements of kokanee from Priest Lake during 1955 and 1956 were composed chiefly of fish in their fifth year of life.

INTRODUCTION

An investigation of Priest and Upper Priest Lakes was initiated in 1955 to determine the harvest, status of fish populations, and life history of important species. The harvest in recent years has changed from one composed principally of cutthroat trout, *Salmo clarki*, to one composed chiefly of kokanee, *Oncorhynchus nerka*. The decline in the quality of the cutthroat fishing has been accompanied by a reduction in the relative number of large fish taken. In addition to the cutthroat trout, Dolly Varden, *Salvelinus malma*, mountain whitefish, *Prosopium williamsoni*, large-scale sucker, *Catostomus macrocheilus*, bridge-nose sucker, *Catostomus columbianus*, northern hawfish, *Ptychocheilus oregonensis*, redside dace, *Richardsonius balteatus*, and peacock bass, *Mylocheilus caurinus*, are indigenous to the lake. Brook trout, *Salvelinus fontinalis*, were introduced about 1920 and are now found in most streams tributary to Priest Lake but are rarely caught from the lake itself. The lake trout, *Salvelinus namaycush*, was successfully introduced into Priest Lake in 1925. The kokanee was introduced in 1942, 1943, and 1944, and is now found in both Priest and Upper Priest Lakes. The rainbow trout, *Salmo gairdneri*, has been planted in the lakes but no specimens were encountered during the course of this study. A small population of greenmouth bass, *Micropterus salmoides*, and green sunfish, *Lepomis cyanellus*, in Priest Lake probably entered through Chase Creek which drains nearby Chase Lake. Priest Lake is joined to Upper Priest Lake by a 2-mile thoroughfare. The lakes are sit-

uated in the Selkirk Mountains and have a coniferous forest watershed of approximately 600 square miles. Priest Lake is 18.5 miles long and 4.5 miles wide with a surface area of approximately 24,000 acres. Upper Priest Lake is 3.2 miles long and 1 mile wide with a surface area of approximately 2,000 acres. Except in limited areas a depth of 40 feet or more is attained within a few feet of shore. The maximum depths found in Priest and Upper Priest Lakes were 355 and 98 feet, respectively.

CREEL CENSUS METHODS

During 1955 three census methods were used to determine the harvest from the Priest Lakes. The first was a resort-owner census in which the operators collected catch data. Resort operators were given census forms and asked to interview fishermen as they docked after completion of fishing. The effectiveness of this method was variable, depending on the resort operators and the numbers of fishermen. The second method employed a census card which was mailed to all persons who owned cabins at Priest Lake. Most of the residents of the approximately 600 private cabins on the lower half of Priest Lake do not use the resort docks. The third method, initiated in September 1955 and used during 1956, was the boat count-interview census. This method did not require the active participation of the resort owners and was designed to contact both cabin-owner and non-cabin-owner fishermen. The amount of non-boat fishing is negligible on both lakes.

The boat count-interview census involves a count of the number of boats to obtain an estimate of fishing pressure, and personal interviews with anglers to determine the rate of

¹Information presented in this paper was derived from a master's thesis, University of Idaho (1957).

catch and species composition. The boat count was made by counting all fishing boats on the lake during a complete circuit of the lake by a census clerk in a boat. Counts took approximately 3 hours and were made at randomly selected times stratified by the interval of the season, day of the week, period of the day, and area of the lakes. The season was divided into 12 intervals of 14 days each, beginning May 1 and ending October 15. The days of the week were divided into three classes: (1) Saturdays and Sundays, (2) Mondays and Fridays, and (3) Tuesdays, Wednesdays, and Thursdays. Each day was divided into four periods and the lakes were divided into five areas. Each period of each class day of the week was sampled once each interval and each area of the lakes was sampled on each count. Thus in each of the 12 intervals, 12 boat counts were made where both lakes were completely circled.

Anglers were interviewed both while they were fishing and after they had finished, but the lack of a central landing area made it necessary to take the majority of the interviews before they had finished fishing.

RESULTS OF CREEL CENSUS

The number of boats observed during a count was usually small, with large numbers being observed infrequently. Consequently, the number of boats per count formed a poisson distribution. In order to facilitate more efficient statistical analysis a square-root transformation, $\sqrt{X + 0.5}$, was used. A factorial arrangement of treatments was used to analyze the boat-count data. All of the interactions were nonsignificant and all of the main effects were found to be significant. Thus the amount of pressure expended during some intervals was significantly different from that expended in others; more people fished on Saturdays and Sundays (approximately 46 percent of total pressure) than on other days of the week; more people fished during the mid-morning (period 2) than during any other period of the day; certain areas of the lakes received more pressure than others; and more boats were found fishing on days with good or fair weather than on days with poor. From the interviews it was determined that 95 percent of the anglers were trolling, 3 percent were fly-fishing, and 1 percent each were spinning and still fishing.

Upper Priest Lake differed markedly from Priest Lake in the percentage of effort expended to catch trout and kokanee. Of the

fishermen interviewed on Upper Priest Lake 49 percent were fishing for kokanee, 44 percent for cutthroat trout, and 7 percent for Dolly Varden. On Priest Lake 84 percent were fishing for kokanee, 7 percent for cutthroat trout, and 9 percent for Dolly Varden or lake trout.

The difference in the rate of catch of cutthroat trout and kokanee in the upper lake and in Priest Lake probably is the most important factor controlling the distribution of fishing pressure. The catch per boat per hour for cutthroat trout in Upper Priest Lake was 1.0 compared to 0.7 for Priest Lake. The rate of catch for kokanee in Priest Lake was 0.9 per boat per hour as compared to 0.9 in the upper lake. Most kokanee fishermen came to fish in Priest Lake where the rate of success was higher even though the fish caught were slightly smaller. Dolly Varden were caught at the rate of 0.7 per boat per hour in the upper lake and 0.4 in Priest Lake. The mean number of fishermen per boat was 1.9 in 1956. Statistical tests revealed that there was no significant difference in the catch of kokanee per hour of those who had finished fishing and those who had not at the time of the interview or between the catch per hour of those persons who had fished a short time and those who had fished for longer periods.

The catch per hour for kokanee was highest during the early summer and fall. As the waters of the epilimnion warmed, the rate of catch of kokanee declined. Those fishermen who fished near the top of the thermocline during midsummer usually had a higher rate of success than those who fished near the surface. When the surface waters began to cool in the fall, the catch per hour increased rapidly to an average of more than six fish per boat per hour.

The estimate of the harvest for 1955 was obtained by combining the totals for the three methods of census used during that year. An estimated 68,700 hours were spent fishing in Priest and Upper Priest Lakes during 1955 to catch 88,100 kokanee and 5,200 trout. The number of hours fished and fish caught in 1956 (Table 1) appear to be higher than in 1955; however, the accuracy of the reservoir owner census in 1955 was not as high as desired and the difference may be only apparent. The estimated number of hours fished during 1956 was found to be reliable within ± 4 percent of the mean at the 95 percent level of confidence. The catch was estimated with confidence limits of approximately 10 percent.

TABLE 1.—Number of hours fished and catch of kokanee, cutthroat trout, Dolly Varden, and lake trout from Priest and Upper Priest Lakes during 1956

Item	Priest Lake	Upper Priest Lake
Hours fished	96,600	7,300
Kokanee caught	102,400	1,600
Cutthroat trout caught	3,600	2,000
Dolly Varden caught	1,600	200
Lake trout caught	300	—

During 1956 approximately 81 percent of the total fishing effort was spent to catch kokanee which in turn accounted for 93 percent of the total catch. Cutthroat trout fishermen expended 10 percent of the total effort to catch 5 percent of the catch. Fishermen catching Dolly Varden or lake trout expended 9 percent of the total effort to catch 2 percent of the total catch.

During 1956 resident fishermen expended 2 percent of the fishing effort and harvested 2 percent of the catch. Anglers originating from private cabins on the lake expended 34 percent of the total fishing effort.

AGE AND GROWTH

Cutthroat trout

In years past the cutthroat trout populations of the Priest Lakes were apparently in much better condition than at the present time. Spawning populations were large enough to support two spawn-taking stations and limit-catches of 20 fish were reportedly common. Since accounts of fishing in the earlier years are woven around the red-bellied spawning it is believed that many of the fish caught were mature fish 13–15 inches long. Limit-catches of 15 fish per day are now rare occurrences, and the average size cutthroat trout caught in 1956 from Priest and Upper Priest Lakes was 11.1 and 11.2 inches total length, respectively. Unlike Henrys Lake in Idaho (Irving, 1954) and Yellowstone Lake (Cope, 1963), the harvest of cutthroat trout from the Priest Lakes in 1956 contained very few mature fish capable of spawning that year.

The body-scale relationship of cutthroat trout from Priest and Upper Priest Lakes was found to be approximately linear. Although it appeared that the scale might grow faster than the body after a fish reaches 12 inches in length, it was decided that the size of the sample and variability of the size of the fish did not warrant the use of the regression method for calculation of body lengths (Whitney and Carlander, 1956). Calculation

TABLE 2.—Mean calculated total length in inches of cutthroat trout that entered Priest and Upper Priest Lakes after spending 1 to 4 years in a stream—samples collected 1956

Years in stream	Number of fish	Years of life					
		1	2	3	4	5	6
Priest Lake							
2	34	3.5	5.8	10.7	12.8	14.4	—
3	51	3.1	5.0	6.9	11.1	13.4	14.6
4	5	3.0	5.0	6.8	8.7	12.2	—
Upper Priest Lake							
1	6	4.2	8.8	12.2	—	—	—
2	35	3.9	5.8	10.8	12.8	—	—
3	51	3.5	5.1	6.8	11.0	13.3	15.4

of body lengths (Table 2) was based on the formula

$$La = a + \frac{SRa}{SRc} (TL - a)$$

where La = length at annulus, TL = total length at capture, a = length of fish at scale formation (1.4 inches), SRa = radius of scale at annulus, and SRc = radius of scale at capture.

Juvenile cutthroat trout were found to spend 1 to 4 years in the tributary streams before entering the lakes. Their scales resemble the scales of sea-run fish which spend 2 or 3 years in fresh water before migrating to the ocean. Block² reports that juvenile cutthroat trout which entered Flathead Lake in Montana also spent 2 or 3 years in tributary streams. Examination of the scales of cutthroat trout taken from Priest Lake in 1956 revealed that 38 percent of the fish had spent 2 years in a stream before entering the lake, 57 percent had spent 3 years, and 5 percent had spent 4 years. In Upper Priest Lake 6 percent of the fish sampled had spent 1 year in a stream, 35 percent 2 years, and 58 percent 3 years.

The habit of cutthroat trout in the Priest Lakes to remain in a stream for 2 or 3 years is reflected in the age-class composition of the catch (Table 3). The catch of cutthroat trout from the Priest Lakes is composed almost entirely of fish in their fourth year of life or older. At Henrys Lake, Idaho, where juvenile cutthroat trout enter the lake during their first year of life, more than a third of the catch is composed of fish in their second and third years of life (Irving, 1954).

² Block, Daniel G. (1957) Trout migration and spawning studies on the North Fork Drainage of the Flathead River. Montana St. Univ., Master's thesis, as reported in Dingell-Johnson Quart., 5(3), January 1957.

TABLE 3.—Age-group composition of cutthroat trout harvested from Priest and Upper Priest Lakes in 1956 and Henrys Lake, Idaho, in 1951—expressed as percentage

Age group	Priest Lake	Upper Priest Lake	Henrys Lake
I	0	0	12
II	1	6	28
III	29	27	33
IV	51	51	19
V	17	14	7
VI	2	2	1

The pattern of growth in fish which enter the lake during their first summer differs markedly from fish which enter the lake after spending more than 1 year in a stream. Irving reports that the rate of growth of Henrys Lake cutthroat trout is most rapid during the first and second years of life and declines rapidly thereafter. The period of most rapid growth for Priest and Upper Priest Lakes cutthroat trout varies according to the number of years spent in a stream before entering the lake. If a fish enters the lake at the beginning of its third year of life, then the third year of life is the most rapid period of growth (Table 2).

Because growth rate in any given year varied in accordance with the amount of time spent in a stream, it became necessary to separate the fish for calculation of body lengths into homogeneous groups based on the number of years of stream life.

The characteristic of juvenile cutthroat trout derived from spawners from the lakes to remain in the streams for 2 or 3 years before entering the lakes creates a situation in most streams where competition for food or space may be very intense and the production of cutthroat trout for the lakes is substantially reduced. The brook trout has become well established in many tributaries to Priest Lake. In those streams which produce a near-capacity crop of fish each year, the juvenile cutthroat trout must compete in many instances with stream-resident populations of both cutthroat and brook trout.

Dolly Varden

The Dolly Varden, indigenous to most waters of the Northwest, is a popular game

fish in Priest and Upper Priest Lakes because it is large. Fish up to 25 pounds have been taken in recent years. The harvest in 1951 was approximately 1,800 fish, taken mostly in the spring and fall.

The Dolly Varden trout in Priest and Upper Priest Lakes apparently spend 2 or 3 years in the streams before migrating to the lakes. Their scales exhibit stream-type development during early years, with the first two or three annuli close together and the next annulus widely separated, indicating change to lake residence.

The body-scale relationship of Dolly Varden from the lakes is not linear. The relationship was found to be best described by a third degree polynomial

$$L = 38 + (0.74) R + (0.0762) R^2 + (-0.000324) R^3$$

derived by selected points method of fitting curves. Scales do not appear until the fish is 1.6 to 1.8 inches long, a length usually attained by August of the first year.

The longevity of Dolly Varden in the Priest Lakes appears to be about 10 years with fish at that age usually attaining lengths of more than 30 inches and weights about 15 pounds. In the Priest Lakes it gains weight most rapidly after reaching a length of 20 inches. A 20-inch fish weighs approximately 3 pounds whereas a 30-inch fish usually weighs more than 10 pounds. The growth rate of fish in Priest Lake was faster than that of those in the upper lake (Table 4).

Kokanee

In the 16 years since its introduction, kokanee has become the most abundant trout in the sport catch from Priest Lake and comprises approximately half the catch from Upper Priest Lake. Since there are no records indicating kokanee were planted in the upper lake, it is assumed that the population in the upper lake originated from fish migrating through the thoroughfare connecting the two lakes. The popularity of the kokanee arises from its excellent eating qualities, large numbers of fish produced for the fishery (c

TABLE 4.—Mean calculated total length in inches of Dolly Varden from Priest and Upper Priest Lakes

Lake	Number of fish	Years of life						
		1	2	3	4	5	6	7
Priest Lake	61	2.8	4.5	7.2	12.2	16.7	20.3	23.8
Upper Priest Lake	41	2.6	4.0	6.1	9.4	14.1	18.2	21.5

ft, 50 per day), and its value as a forage for the larger trout.

The body-scale relationship of kokanee in Priest and Upper Priest Lakes was found to be approximately linear with a tendency for the body to grow faster than the scale during the last year of life. A straight-line relationship was assumed and back calculation of body lengths at various ages was made with the formula described for the cutthroat trout, except that an intercept of 1.2 inches was used. Scales collected in 1955 from older kokanee appeared either to have added a full year's growth by July or none at all. During 1956 growths, weights, and scale samples were collected at bi-weekly intervals beginning in May to determine the time of annulus formation. Kokanee in their second and third years of life usually form an annulus in June, while those in their fourth, fifth, and sixth years did not form an annulus until July. In a few cases it appeared that no circuli were laid down during the last year of life. Fish in their third year seemed to grow at a slightly faster rate in the spring and early summer than did older age groups. Also the rate of growth of fish in their fourth, fifth, and sixth years decreased noticeably after August 1.

Sampling restrictions limited the determination of age composition to the sport catch and spawning populations. From scale analyses of length measurements it was determined that age-groups II, III, IV, and V were represented in the 1956 harvest. Age-group IV was the most abundant group (84 percent) of the Priest Lake harvest followed by age-groups II (6 percent) and III (8 percent). Age-group V made up an estimated 1 to 2 percent of the total harvest. The 1955 harvest consisted predominantly of IV-annulus fish.

The 1956 harvest from Upper Priest Lake consisted of nearly equal percentages of age-groups II (26 percent), III (28 percent), IV (26 percent), and V (21 percent). Age-group V made up the remaining 2 percent.

Kokanee in both Priest and Upper Priest Lakes usually attain a length of 3 inches during their first year (Table 5). The difference in size between Priest and Upper Priest Lake is the result of differing growth rates during the second, third, and fourth years of life. The growth of Upper Priest Lake fish exceeds that of Priest Lake kokanee by as much as 1 inch during the second and third years of life.

Intraspecific competition for food, space, and spawning site appears to be an important

TABLE 5.—Mean calculated total lengths and increments of length (parentheses) of the 1951 year class of kokanee taken from Priest and Upper Priest Lakes—expressed in inches

Lake	Years of life			
	1	2	3	4
Priest Lake	3.2 (3.2)	6.9 (3.7)	8.5 (1.6)	9.7 (1.2)
Upper Priest Lake	3.6 (3.6)	8.0 (4.4)	10.6 (2.6)	12.1 (1.5)

factor affecting the size of kokanee. Although intraspecific competition probably does not result in the death of a fish, it does appear to affect its food consumption and growth rate. Foerster (1944) found a significant inverse correlation between the size of the lake population of sockeye and the size of the migrants. In Priest and Upper Priest Lakes there have been statistically significant differences in the growth rate from one year to another.

The larger size of the kokanee in Upper Priest Lake as compared with those in Priest Lake is probably due to a smaller population density in the upper lake as indicated by the much lower catch per hour by fishermen.

During the course of the investigation it was believed that there might be differences in the size of kokanee from various areas of the lake. Johnson (1956) found that young sockeye were not distributed evenly throughout the lakes he studied. Because of this uneven distribution he felt that the fish were not fully utilizing the food resources present and thus there may have been a significant effect on their size. Samples were taken in each of four areas of Priest Lake, but statistically significant differences in size (95 percent level) of age-group IV fish from different parts of the lake were not found.

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Plankton Pigments in East Lagoon, Galveston, Texas

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ABSTRACT

Pigment analyses have been made of a lagoon emptying into the Gulf of Mexico. This water showed a typical cycle of early spring flowering, later spring minimum, summer oscillations, and a secondary early fall maximum. The cycle resembled those of more northern waters, but the blooms in East Lagoon occurred earlier in the year. The bloom periods were related to various physical factors—solar radiation, temperature, and rainfall—with a direct relationship between incident radiation and chlorophyll *a* production indicated for the fall of 1957. The chlorophyll production of the lagoon compared favorably with other waters in these latitudes, yielding a mean of 17.6 mg chlorophyll *a*/m³ during the sampling period from October 1957 to May 1959. An analysis of the precision of the method indicated a standard error of 0.565 ± 0.085 mg/m³ for chlorophyll *a* and 1.35 ± 0.165 MSPU/m³ for chlorophyll *c*. The large value for the latter pigment is attributed to the method of calculation.

INTRODUCTION

The analysis and measurement of plankton pigments is now a standard practice in the fields of limnology and oceanography. Dating from the time of Willstätter and Stoll who related plant pigments (more particularly chlorophyll *a*) to the amount of photosynthesis, various authors have used this measurement either to indicate standing crop or as an index of the potential production of an area (Ryther, 1956). In the present report pigments have been used as an index of standing crop in a sub-tropical estuary in conjunction with a study of the effects of a copper ore dike upon the ecology of East Lagoon, Galveston, Texas. Data were gathered for 11 months prior to the addition of copper ore in the lagoon and for the following 9 months. Since no marked effects due to the ore itself were noted (Marvin, 1959), only the effects of the yearly climatic cycle upon the standing crop and potential production will be discussed.

METHODS

The lagoon is a narrow body of water 1.1 miles long and 230 feet wide at the narrowest point with a volume of approximately 75 million gallons. Figure 1 shows the location of the lagoon and the sampling stations with reference to the Houston Ship Channel. The Gulf of Mexico is approximately one-fourth mile south of the lagoon at its closest point. Stations were numbered from the head of the lagoon, with station 1 being the deepest (4.4 meters) and receiving the greatest amount of drainage from the surrounding marsh. Stations 7 and 8 at the mouth of the lagoon were 2.5 meters deep and were subject to greater tidal action than the others. The ore dike,

when established, was placed between stations 3 and 4 which were intermediate in depth. All stations were along the deeper axis of the lagoon.

The frequency of sampling varied during the experimental period. With few exceptions samples were taken at least twice each week from the inception of the work in October 1957 until the end of October 1958, after which weekly samples were taken. Eight stations were sampled until December 1958 when the stations sampled were reduced to stations 1, 4, and 7. Samples were taken at the same time of day to minimize differences due to light intensity.

Fifty gallons of water were pumped into a polyethylene drum at each station while the intake hose was moved up and down from the surface to within a foot of the bottom. The temperature of this composite sample was taken, and 2-liter samples were then removed for analysis. Salinities were taken with a hydrometer and the samples treated with MgCO_3 immediately upon return to the laboratory. After overnight storage in a refrigerator, the samples were stirred and 1 liter filtered through a Millipore apparatus (Criss and Richards, 1955) and the residue extracted with 90 percent reagent-grade acetone (Richards and Thompson, 1952) for the determination of plankton pigments. The extraction

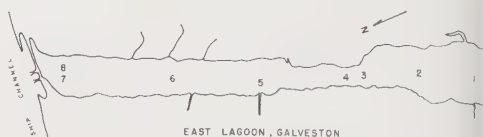


FIGURE 1.—East Lagoon, Galveston, Texas, showing stations sampled.

TABLE 1.—Precision of the method

Pigment	Number of samples	Mean pair difference (MSPU or mg/l of extract)	Standard error of mean
Chlorophyll <i>a</i>	141	0.113	±0.017
Chlorophyll <i>b</i>	141	0.060	±0.008
Chlorophyll <i>c</i>	141	0.270	±0.033
Astacin-type carotenoids	141	0.030	±0.003
Non-astacin carotenoids	141	0.072	±0.006

allowed to proceed in the dark for 18 to 24 hrs at room temperature after which the optical densities of the extracts were read in Beckman DU spectrophotometer at 665, 645, 625, 510, and 480 $m\mu$ and the amount of pigment calculated.

PRECISION OF METHOD

For the first 2 months of the project each water sample was divided in half and each half filtered, extracted, and read as a separate determination. Table 1 shows the precision obtained upon 141 of these duplicate samples. Chlorophyll *c* values showed greater pair differences than those of any other pigment. This may in part be ascribed to the method of calculation, for instrumental readings are multiplied by a factor of 100. Thus a slight instrumental or operator error may have resulted in larger variations in the final calculated value for chlorophyll *c*. Greater pair differences in chlorophyll *a* tend to occur when larger quantities of pigment are present. This may be due in part to errors in extraction, as noted by Odum, McConnell, and Abbott (1958), when plankton blooms are occurring. Extraction errors may result from the presence of heavily walled organisms which are difficult to break up with the usual trituration and extraction so that duplicate samples may not be extracted equally well. There may also be a constant percentage error inherent in the procedure, resulting in larger differences at lower pigment concentrations.

A second type of precision study was also carried out. Fifty gallons of water were sampled from a single station, and from this amount eight 2-liter samples were returned to the laboratory for analysis. Duplicates of each sample were analyzed as described in the preceding section. These analyses indicated that the values reported for the duplicates were as precise as the values for replicates from one sample. For this reason, only single samples were taken during the latter phase of the project.

TABLE 2.—Destruction of pigments by heat and light

Pigment	Original concentration (mean)	Final concentration (mean)	Percentage of original
Chlorophyll <i>a</i>	4.55 mg/l	2.09 mg/l	45.0
Chlorophyll <i>b</i>	0.18 mg/l	0.12 mg/l	63.7
Chlorophyll <i>c</i>	2.03 MSPU/l	1.36 MSPU/l	66.9
Astacin carotenoids	0.26 MSPU/l	0.31 MSPU/l	123.1
Non-astacin carotenoids	1.33 MSPU/l	0.65 MSPU/l	46.0

A further check was made on the stability of the pigments in samples untreated with $MgCO_3$ and not refrigerated. The $MgCO_3$ served to prevent the breakdown of the chlorophylls to the corresponding pheophytins whose absorption peaks do not correspond to the peaks of the original compounds. Refrigeration inhibited bacterial action, as well as the action of light and heat in the destruction of the pigments. A single set of eight samples (duplicates of a set previously treated and analyzed) was held without the addition of $MgCO_3$ at room temperature for 3 days following collection. At the end of this time they were treated, extracted, and read as usual. The change in each type of pigment under these conditions emphasized the need for prompt treatment and analysis (Table 2). It further indicated the necessity for analysts, in reporting on work of this kind, to state the type of treatment given to the sample and the length of time it was held prior to analysis.

Table 2 shows that about 55 percent of both the chlorophyll *a* and the non-astacin carotenoids were destroyed by room light and temperature. Chlorophyll *b* and *c*, on the other hand, have suffered only about 35 percent destruction, and the astacin-type carotenoids have apparently increased. Some of these differences are undoubtedly due to the spectral shifts, mentioned above, when a pigment is converted to a degradation product. However, it is noteworthy that the chlorophyll *c* values remained relatively high so that the chlorophyll *a* to chlorophyll *c* ratio, which has been used by some authors to characterize inshore and offshore waters (Currie, 1958), decreased by about one-third.

RESULTS OF SURVEY

As stated earlier, the regular sampling of the lagoon for plankton pigments began in October 1957 and continued until the end of May 1959. Figures 2 through 7 show the cycle in the lagoon of chlorophyll *a* (mg/m^3), chlorophyll *c* ($MSPU/m^3$), non-astacin or plant-type carotenoids ($MSPU/m^3$), solar ra-

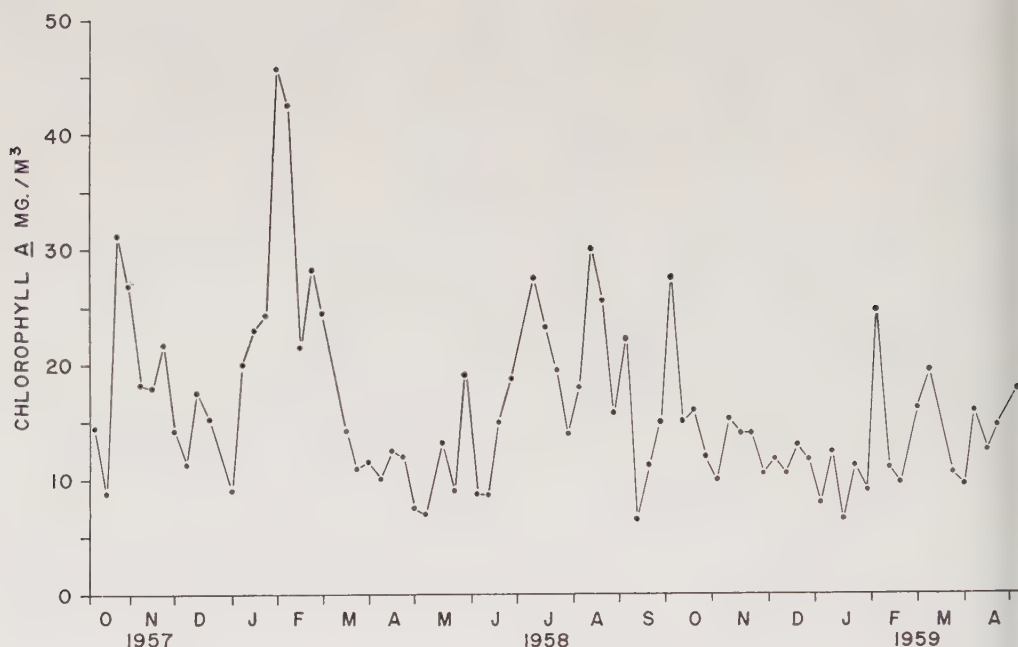


FIGURE 2.—Variation in weekly means of chlorophyll *a* measurements

diation, air temperature, salinity, and rainfall. The values for all data are expressed as the daily mean of all stations for a weekly period (other than rainfall which is expressed as total rainfall per week). The solar radiation data were calculated by the method of Fritz and MacDonald (1949) using the data of the Galveston Weather Bureau for percentage of possible sunshine per day. The air temperatures are means of the daily Weather Bureau observations. Salinity and pigment quantities are means only of the days and times at which samples were taken.

Figure 2 presents mean daily chlorophyll *a* concentrations for the eight stations for the entire period of sampling. An early fall maximum occurred in October in both 1957 and 1958, with a maximum mean of 31.2 mg/m³ in 1957 and 26.8 mg/m³ in 1958. The spring phytoplankton flowering began early in January of 1958, and reached its peak during the last week of the month when the mean chlorophyll *a* concentration reached the maximum of 45.8 mg/m³. The highest value recorded during the bloom was 61.1 mg chlorophyll *a*/m³ at station 1, but values of 50 mg/m³, or more, were recorded at all stations. The bloom gradually decreased to a spring and early summer minimum in the months of March through June, followed by a gradual

increase with periods of oscillation during July and August. This latter period was characterized by patchy euglenoid blooms throughout the lagoon area, and during one of these the highest value of the survey, 84.5 mg/m³, was recorded at station 1. This was followed by a more general bloom throughout the lagoon, with a mean of 29.8 mg/m³, but values were never again as high as those recorded during the spring of 1958. Conditions during September 1958 were disturbed by hurricane Ella which flooded the entire lagoon area introducing large amounts of salt and fresh water. This flooding was immediately succeeded by a marked drop in chlorophyll and other pigments to the minimum for the observation period, but the depression was only temporary. Immediate increases in values indicated a fall bloom which did not reach the proportions of the fall bloom of 1957. This bloom was followed by a prolonged winter period of low concentrations with a minimum in January. The spring maximum of 1959 occurred in early February, approximately 2 weeks later than in 1958, and apparently did not reach the height of the bloom of the year before. These data, however, must be interpreted cautiously since there was a period of almost 3 weeks when no samples were taken, and both sampling frequency and

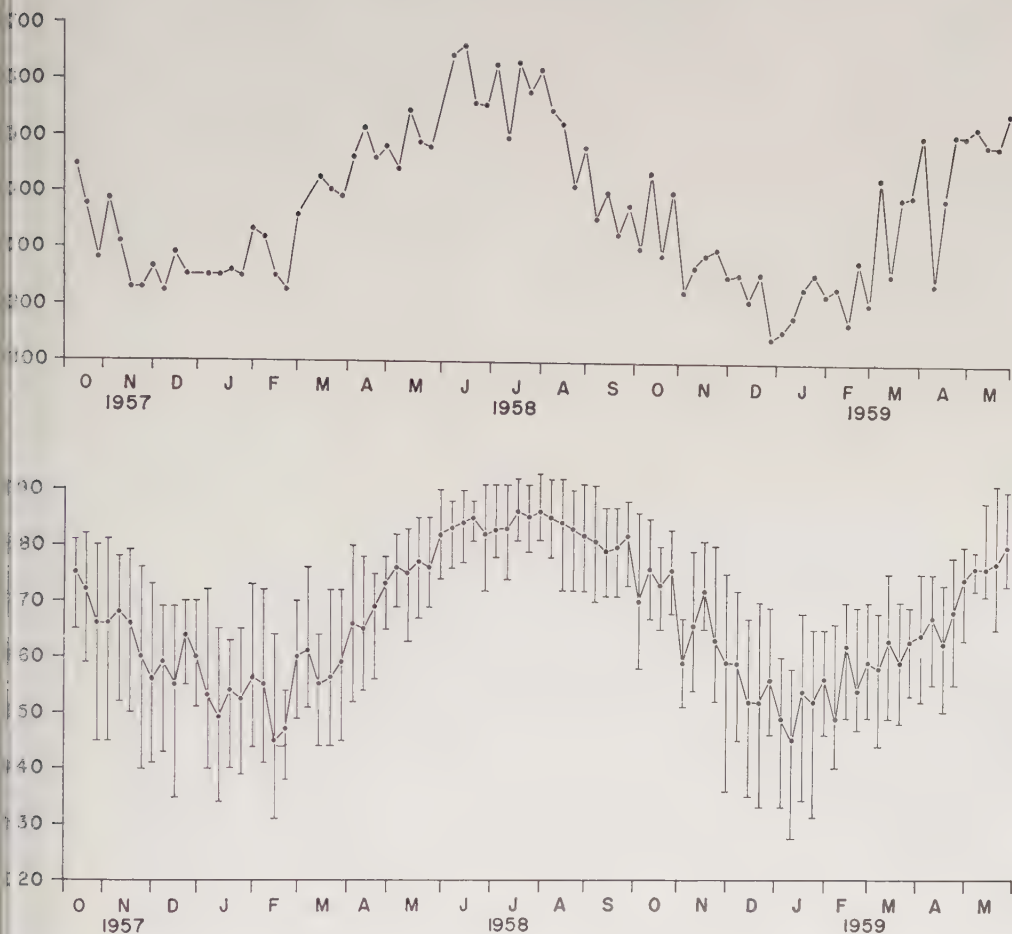


FIGURE 3.—Mean weekly solar radiation and air temperature for the Galveston area. Vertical lines on temperature graph show the temperature range for each week.

number of stations sampled had been placed. The highest value recorded during the period was 26 mg chlorophyll *a*/m³ from station 1. Thus, this body of water showed evidence of a cycle in phytoplankton flowering with peaks in chlorophyll quantity in January or February and again in October–November. The minima occurred in December–January and again in April–May.

The differences in the crops of these years, as shown by the pigment analyses, may be explained in part by the accompanying physical conditions. The solar radiation graph (Figure 3) clearly indicates that there was considerably less light reaching the area during the late fall and winter of 1958 than during the corresponding period of 1957. Similarly, temperatures were lower during the winter of 1958. Since light and heat are two of the

requisites for a bloom, the reduction of these may have delayed its onset in the spring of 1959.

Scatter diagrams of solar radiation versus chlorophyll present in the water indicated no relationship that held for the entire period. As has been noted in more northern waters (Smayda, 1957), the autumn and spring flowerings occurred at a time when the radiation curve was changing more or less rapidly. In East Lagoon there was a direct relationship between radiation and chlorophyll *a* for 10 weeks during 1957 (October through December) when the mean daily solar radiation was plotted against the mean daily chlorophyll of the second following week (Figure 4). The relationship would seem to indicate that at the period of declining bloom, light itself may have been the factor limiting the bloom. At

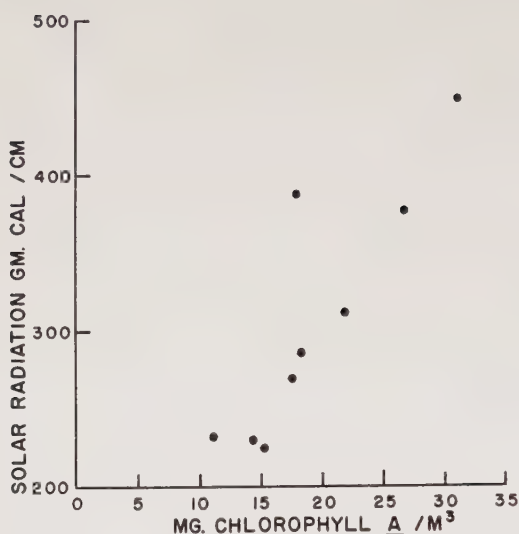


FIGURE 4.—Relation of mean solar radiation and mean chlorophyll *a*, October through December 1957.

no other period during the survey could any relationship be found. Several factors might have been responsible for the lack of correlation in the fall of 1958. They were hurricane Ella, which occurred early in September and flooded the entire area; the presence of the copper ore dike which was placed between stations 3 and 4 during August and October; and the decreased sampling frequency which might have masked the effect of light since the graphs are based on weekly means. In any case, during other periods of the survey other factors apparently had more influence on the growth of phytoplankton than solar radiation.

RELATIONSHIPS OF THE PIGMENTS TO ONE ANOTHER

Generally it may be stated that chlorophyll *c* rose and fell with the rise and fall in chlorophyll *a* (Figures 2 and 5), with the highest recorded value 34.2 MSPU/m³ at station 1. In one bloom period chlorophyll *c* tended to drop somewhat later than chlorophyll *a*. Chlorophyll *c*, however, apparently was not destroyed as rapidly in the laboratory as chlorophyll *a* so that its later decline may have been an artifact. The ratio of chlorophyll *c* to chlorophyll *a* was greater than one in only 49 of 962 samples examined. This finding agrees with Currie (1958) who stated that ratios below one were characteristic of inshore waters, while the higher values appeared to

be characteristic of offshore waters. The differences in ratio may be indicative of change in population type, since Strain *et al.* (1943) and others have shown that diatoms and dinoflagellates are relatively rich in chlorophyll *c* whereas this pigment is absent from euglenoids and green algae.

Though fairly large quantities of chlorophyll *b* occur in terrestrial plants, only small quantities occur in many planktonic forms. During these investigations the highest recorded value was only 6.7 mg/m³ in the bloom of 1958 when euglenoids were known to be present. There were only eight samples examined in which the chlorophyll *b* concentration reached 5.0 mg/m³. Even in these samples, however, the chlorophyll *b* was found to represent less than 20 percent of the chlorophyll *a* value and less than 10 percent of the total chlorophyll present. In most cases chlorophyll *b* was found to be less than 5 percent of the chlorophyll *a* value, as might be expected in populations consisting largely of diatoms, dinoflagellates, and euglenoids (Strain, 1951). Ratios above 10 percent occurred with slightly greater frequency at station 1 than at any other station in the lagoon. This probably indicates a slightly different type of community in this area, which is also the site of the heaviest bloom found in the lagoon and the greatest single chlorophyll concentration reported during the entire survey.

Although the carotenoid pigments tend to increase with the chlorophyll concentration, this was not always the case (Figure 5). In winter, especially, the chlorophyll concentrations were relatively much higher than the carotenoids. This may indicate that there were changes in both type and physiology of the population since it is known that with decreasing light, plants, and plankton as well as tend to increase in chlorophyll content.

Pigment production has been expressed on an area basis following the work of Gessner (1949) who showed that equal areas on land and water are capable of producing the same amount of chlorophyll. Using this method it was possible to compare the pigment produced at various stations within the lagoon. As mentioned above, station 1 is the deepest station, with stations 7 and 8 the most shallow. Converting chlorophyll *a* from the amount per cubic meter to the amount per square meter (the quantity of chlorophyll beneath a square meter of illuminated surface)

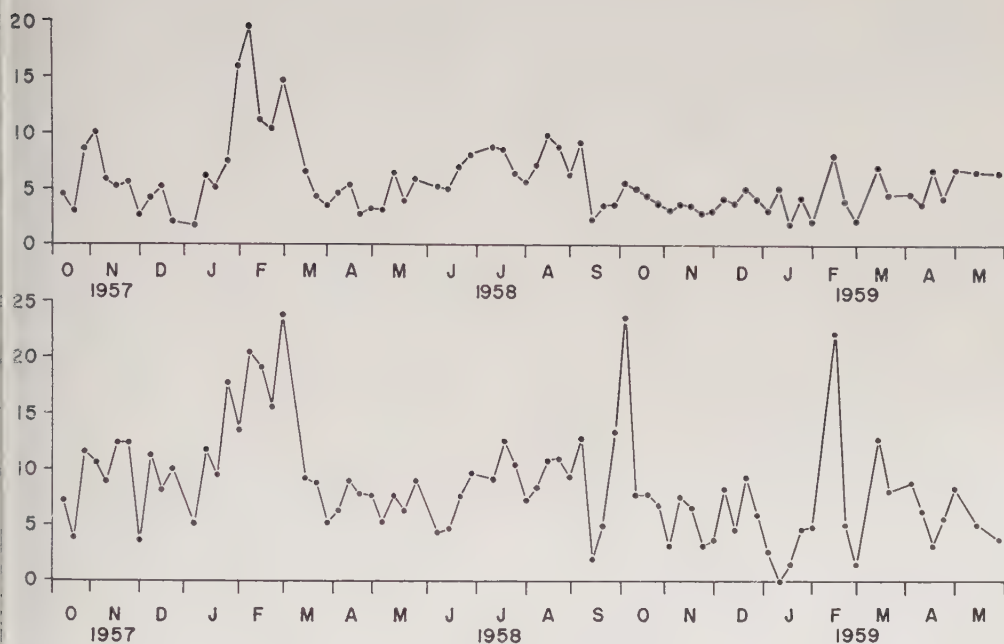


FIGURE 5.—Variation in weekly means of chlorophyll c and non-astacin carotenoids.

is the chlorophyll per cubic meter times depth of the water column in meters), the amount of incident radiation yielded

more pigment at the head of the lagoon (station 1) than at the mouth (station 7) for most sampling periods (Figure 6). Values at sta-

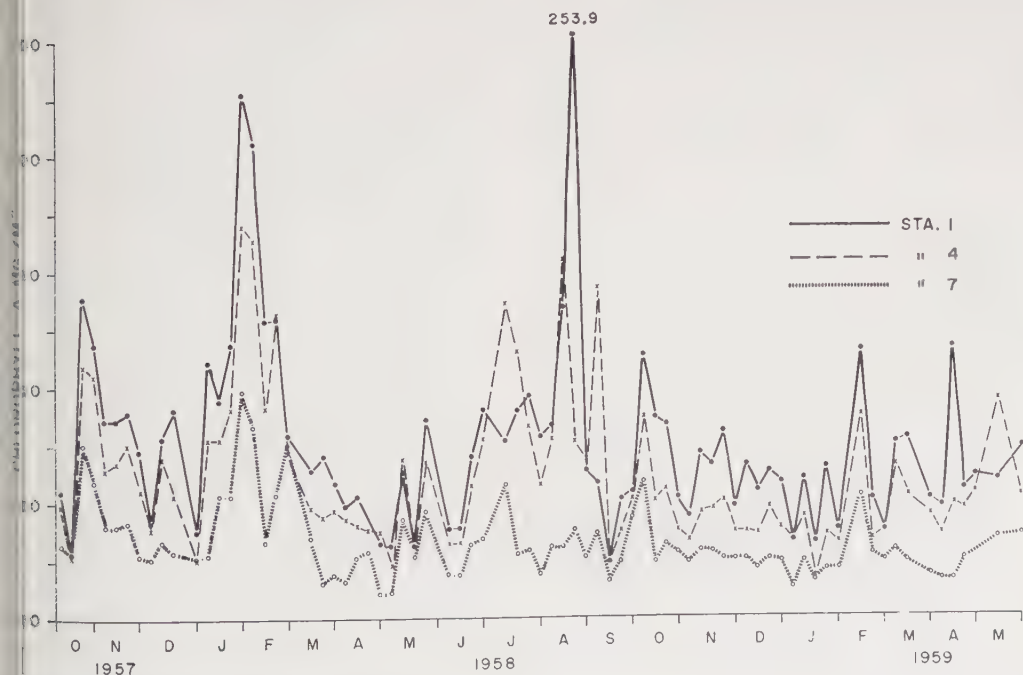


FIGURE 6.—Station variation in chlorophyll a.

TABLE 3.—*Variations among stations for period of observation*

Station	Mean chlorophyll <i>a</i> (mg/m ³)	Standard error of mean	Range (mg/m ³)	Mean chlorophyll <i>a</i> (gm/m ²)
1	18.50	1.0	2.2–84.1	0.08
4	18.95	0.98	5.0–72.2	0.07
7	15.25	0.75	3.0–51.5	0.04

tion 4, in the middle of the lagoon, were intermediate. Table 3 gives the station variations on both volume and area bases.

Although the differences between stations 1 and 4 are not significant on an area basis, those between stations 1 and 7 and between 4 and 7 are highly significant. This is true for chlorophyll *c* as well, but the differences in mean values for the plant carotenoids (non-astacin type) are not significant. These facts together with variations in chlorophyll *b* and *c* previously cited further indicate the dissimilarity in production of the various segments of the lagoon. Although the spring bloom was found in all stations of the lagoon, the late summer bloom (August 1958) was largely limited to the upper segment of the lagoon (stations 1 to 4) in which the highest chlorophyll concentration of the survey was found.

Several factors may have influenced this gradient in production. First, the stations themselves varied in depth so that even at times when the pigment per unit volume of water was similar, the pigment per square meter was almost twice as great at station 1 as at station 7. Second, there was a correlation with change in tide. A comparison of the occurrence of a chlorophyll gradient along the length of the lagoon and the tidal conditions (as recorded at Fort Point, approximately one-half mile from the lagoon proper) showed that gradients were steeper and occurred more often when the tide was changing, and that gradients were weaker and less frequent with standing tides. Station 7 was obviously far more subject to both tidal and current action than the stations nearer the head of the lagoon and was less apt to receive the enrichment from the drainage of the surrounding marsh than station 1. Since it was likely to be more turbid than the other stations due to this tidal action, there may have been an effective decrease in the amount of light reaching the area as well as a dilution due to the influx of poorer Gulf waters. The combination of these factors may explain why this station appeared to be a poorer producer than those along the upper reaches of the lagoon.

There were no data on turbulence, thermal stratification, or nutrient cycles in East Lagoon which would further explain the differences along the length of the lagoon or periods of bloom. A study of the nutrients of the lagoon was made for a single 24-hr period during July 1958. The inorganic total phosphorus had values of about 2.5 at. /m³. There was some evidence that station 7 had slightly less phosphorus than the upper stations (about 0.1 mg at. /m³ during the period of study). Station 7 also showed less chlorophyll than either stations 1 or 4, station 1 having not only the greatest amount of chlorophyll but also showing an increase in chlorophyll during the midmorning followed by a decline toward darkness. These samples were taken 1 foot below the surface rather than from the entire water column.

A comparison of the phytoplankton production with zooplankton data collected simultaneously indicated similar differences among stations along the lagoon, although the gradient is apparently reversed. Station 7 was by far the richest in production of zooplankton, while stations 1 and 4 similar to one another were much poorer producers. A small peak of zooplankton abundance was evident in December 1957, following the October and November phytoplankton bloom, but there was no apparent increase immediately following the very large peak in late January and February (Fleminger, 1959). On the contrary, the zooplankton began to increase late in April to May when the phytoplankton (as judged by the pigment concentrations) was on the wane. The zooplankton population, in fact, began to die out during the late summer when the phytoplankton was again reaching periodic bloom. Both declined during the midwinter of 1958–59 and then showed an apparent increase in February of 1959. It has been postulated that grazing plays a large part in the decline of phytoplankton (Riley, 1946; Riley and Bumpus, 1946), and during the summer months this would be indicated both by low zooplankton populations at the time when phytoplankton was apparently low and by the inverse relationship of phytoplankton and zooplankton along the length of the lagoon.

Physical factors may also influence the genesis of the blooms noted above. Solar radiation itself did not appear to have a direct correlation with pigment production during one period of observation. There was apparently a more direct relation with rainfall (Figures 2 and 7). Although a period

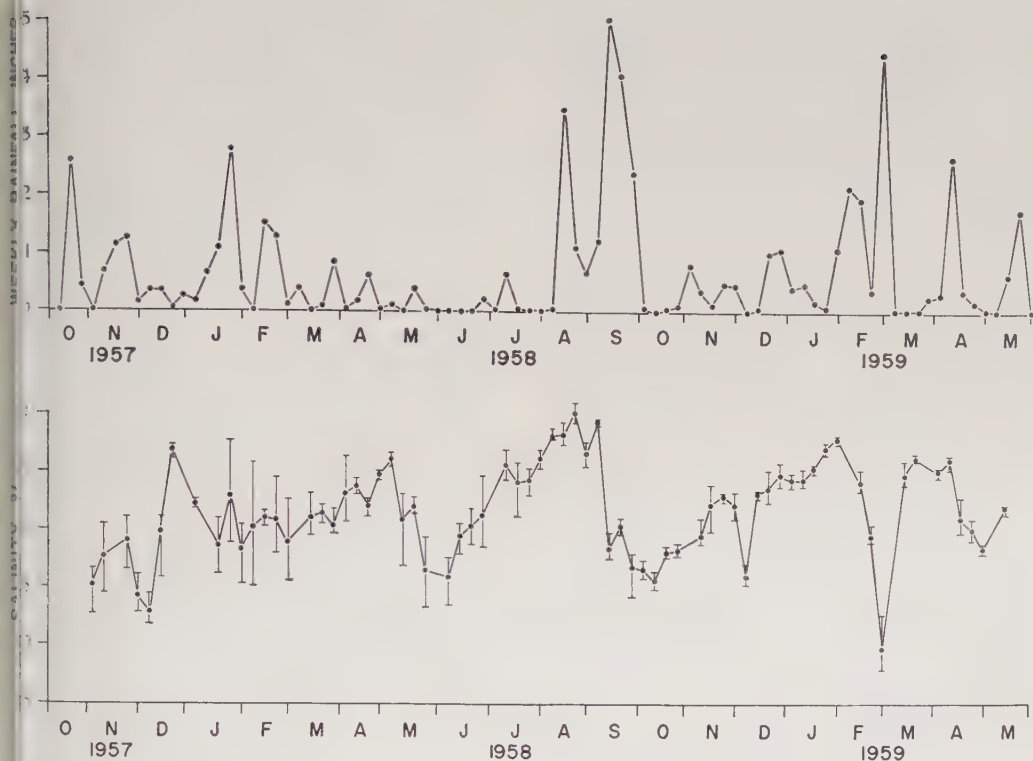


FIGURE 7.—Total rainfall for the Galveston area and mean salinity, East Lagoon.

any rainfall alone may not be sufficient to bring about a bloom, rainfall was probably a necessary condition as each bloom was either preceded by (not more than a week) or coincided with periods of relatively heavy rain. Further, chlorophyll was minimal during weeks and months when rainfall was low. The immediate effect of hurricane conditions was a decrease in pigment, due in all probability to the dilution and replacement of the lagoon water by both rain and drainage of surrounding areas and from the Gulf inlet. The hurricane was followed within a week, however, by an increase in pigment concentration. Smayda (1957) has noted the same condition in Rhode Island following hurricanes of the 1954 season and attributed the immediate appearance of the phytoplankton blooms to an increase in phosphate and iron concentrations. Whether these particular enrichments occurred in the lagoon was not ascertained, but it does seem likely that there was enrichment due to the large influx of drainage water from the surrounding marsh and from the river discharge. Mean salinity generally was correlated with rain-

fall and with season. Values ranged from 8.0 parts per thousand following a heavy winter rain to 31.2 parts per thousand during the late summer. The mean salinity for the entire lagoon for the period of observation was 20.8 parts per thousand.

DISCUSSION

It is necessary to view all results such as these with some caution. When samples are taken several times during the week, conclusions are more firm than when sampling is less frequent. As Rodhe (1958) says concerning the C^{14} method (and it is equally applicable to this type of determination):

The conclusion that can be drawn . . . is that a sampling frequency as high as once a week need not warrant a true picture of temporal succession. . . . Under such circumstances, we get one picture on the basis of samples taken every Monday, but perhaps should achieve quite different peaks and feet in a curve derived from samples taken on Tuesdays, etc. . . . Straight lines connecting weekly dots . . . cannot be regarded, *a priori*, as representative of the course of events during the other six days of the week, neither for the sampling station nor for the lake as a whole. In general, therefore, when

we have to illustrate the seasonal succession, histograms are preferable to smooth or broken curves which easily give the impression of more complete information than the primary results permit.

As mentioned above, the curves given in this paper are averages of all stations for all collections during a given week. Variations in daily means of chlorophyll need not be representative of actual population changes in the lagoon since chlorophyll content changes with the physiological state of the organism, being influenced by nutritional state (lack of essential minerals such as iron), amount of available light, etc. In addition, Rodhe (1958) has demonstrated that chlorophyll content may undergo vast changes from day to day, sometimes of the order of several hundred percent, so that it would be preferable to show actual daily station data. This method would emphasize the fact that frequency of sampling markedly influences the weekly means. Let us compare the two spring blooms, for example. In 1958, samples were taken almost daily so that the weekly average presumably includes the highest chlorophyll values attained during the flowering. In 1959, however, only three stations were being sampled and these at somewhat irregular intervals so that the highest value recorded may not have been the true peak. Since flowerings are notably patchy and occur and diminish with great rapidity, particularly in warmer waters such as those found in the Gulf areas, productivity cannot be accurately quantified unless frequent and regular samples are obtained. Seasonal cycles, however, will be evident.

Seasonal cycles in East Lagoon indicate blooms in January or February and again in October–November with minima in December–January and again in April–May. Atkins and Parke (1951), Atkins and Jenkins (1953), and Jenkins (1955) have reported cycles based on monthly surface samples from the English Channel with maxima in March or April, followed by a decline to a summer minimum and a secondary maximum in September or October. Riley (1946) and co-workers have described similar cycles in Georges Bank and Long Island Sound. In Long Island Sound (Riley and Conover, 1956; Conover, 1956) there was an annual cycle characterized by a large late-winter flowering, with lower values throughout the spring and summer, small sporadic flowerings in summer and early fall, and minimal populations in late fall and early winter. All three studies show similar cycles

although the exact time of appearance of late-winter bloom is dependent upon latitude.

Wide ranges in chlorophyll content have been reported. East Lagoon has yielded a maximum chlorophyll *a* of 84.6 mg/m³ for the entire sampling period, with a mean of 17.6 mg/m³. Marshall (1956), in studies of Florida coastal waters, reported a maximum of about 14 mg chlorophyll *a*/m³ in Alligator Harbor and a mean of 4.3 mg/m³. Both are considerably below the values reported here. Even the value of 30.7 mg/m³ found by Marshall in the midst of a bloom of *Gyrodinium aureolum* is considerably below the values determined in the midst of blooms in this study. In the Tortugas, Riley (1946) found a mean of 0.33 mg/m³ of chlorophyll *a*, but these analyses covered only a 2-week period, from July 18 to August 2, when his data from my data and from the data of Marshall (1956) it would appear that chlorophyll concentration may not be at its height. Aguirre (1939) reporting on the western North Atlantic in May and June of 1939, noted that the tropical waters had a maximum of 2.5 mg chlorophyll/m³ to the 3.6 mg/m³ of the more northern waters. In Long Island Sound (Riley and Conover, 1956; Conover, 1956) the maximum chlorophyll *a* value was considerably lower than that in the enclosed water of East Lagoon, with a maximal value for the years 1954–1955 through February 1954 of only 30 mg/m³.

Plankton production data from southern regions are somewhat scarce. Odum, McNeill, and Abbott (1958) have reported chlorophyll per square meter for several plankton communities in Texas. Their work indicates that the Texas bays generally yield from 0.043 to 0.200 g chlorophyll *a*/m² with a minimum of 0.002 g/m² in the Laguna Madre. East Lagoon has given values ranging from 0.044 to 0.37 g/m². The latter value in the midst of a plankton bloom (euglenote) compares with bloom values from various more northern regions ranging from 0.10 to 0.6 g/m² (Odum, McNeill, and Abbott, 1958). Generally, pigment concentrations in East Lagoon may be considered to be higher than those reported by other workers in open waters, though the maximal concentrations do not reach those reported by others in the midst of special types of plankton blooms.

Organic productivity in the lagoon may be compared with that found in other envi-

ms, following the equation of Ryther and Yentsch (1957):

$$P = \frac{R}{k} \times C \times 3.7$$

where P is productivity in grams carbon per square meter per day, R is a radiation factor obtained from the graphs of Ryther and Yentsch (1957), k is the extinction coefficient of the water, and C is grams of chlorophyll per cubic meter. Assuming an average radiation of 350 cal/cm² for the period of observation, an average k of 1.7 (estimated from the average 5-mi-disk readings by the method of Poole and Atkins, 1929), and using the mean chlorophyll a for the lagoon of 17.6 mg/m³, there was an average production of 0.27 g carbon/square meter per day or 0.5 g dry organic matter/m² per day. The maximal productivity was 1.74 g/m² per day, or assuming the organic production to be 50 percent carbon, 3.5 g dry organic matter/m² per day. These approximations compare with maxima for a single day reported by Ryther (1959) of 2.8 g/m² per day in the Sargasso Sea with an annual average of 0.9 g/m² per day in Long Island Sound.

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Production and Survival of Eggs of the American Smelt, *Osmerus mordax* (Mitchill), in Maine¹

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ABSTRACT

Egg production and egg survival of the American smelt, *Osmerus mordax* (Mitchill), were studied during the 1958 spawning run at Dean Brook, Ellsworth, Maine. The construction, number, and location of sampling units utilized in the estimate of egg production and egg survival are discussed. Egg production was $13,726,351 \pm 3,525,971$ and egg survival was $3,423,177 \pm 610,384$. Regressions of egg density and egg survival upon distance above the stream mouth are computed. An index of spawning activity could not be related to observed environmental variables. A density of smelt eggs for hypothetical maximum prolarval production was 11,745 eggs per square foot. Maximum prolarval production occurred in regions of moderate smelt egg deposition. Sources of egg mortality are noted and a nonstatistical estimate of prolarval production is presented: 75,440. A total egg mortality of 99.5 percent is indicated.

INTRODUCTION

Fresh-water populations of the American smelt, *Osmerus mordax* (Mitchill), are important as salmonid forage, as possible competitors and predators of salmonids, as sport fish, and as bait. The Maine Department of Inland Fisheries and Game has therefore undertaken a statewide investigation of the life history and ecology of fresh-water smelt populations. As a part of that investigation, this study developed techniques for estimating smelt egg production and subsequent egg survival and also investigated some of the phenomena associated with the deposition of smelt eggs. Field work was done during the 1958 smelt spawning run at Dean Brook, a tributary entering the northwest portion of Branch Lake, Ellsworth Township, Hancock County, Maine. This stream was chosen because it was reported to have the largest smelt run of any Branch Lake tributary; it was readily accessible, small, and easily observed.

Branch Lake is oligotrophic, has a surface area of 2,703 acres, 12 inlet tributaries, a maximum depth of 124 feet, a mean depth of 39 feet, and contains populations of typically cold-water fish.² Dean Brook, fed by runoff and spring seepage, is generally of moderate gradient. During these studies the flow varied from approximately 4 to 6 cubic feet per

second. Vegetation was sparse in the stream area. There is a falls, impassable to migrating smelt, 145 feet from the stream mouth (Figure 1). The upper area of spawning (zones A and B) had maximum depths of about 2 feet. In the upper spawning area bottom materials were sand and coarse and fine gravel. Lower portions of the spawning area (zone C) had maximum depths of about 4 feet and bottom material included localized concentrations of silt.

SAMPLING TECHNIQUES

Spawning smelt broadcast highly adhesive eggs which become attached to the stream substrate. A sampling unit was designed to which smelt eggs would adhere. Enumeration of eggs on the sampling units placed throughout the spawning area provided samples of egg density and egg survival which were used to estimate egg production and egg survival parameters. A sampling unit consisted of a glass black ceramic tile, $4\frac{1}{4}$ inches square, with egg-depositional surfaces of heavy black canvas strips, 2 inches wide and about 5 inches long. The 2-inch ends of each strip were joined by a rubber band stapled to each end which formed a collar-like arrangement which permitted each strip to be slipped easily on and off the tile.

Utilization of sampling units required several assumptions to be made. The first is that attachment of eggs to depositional surfaces was equivalent to their attachment to natural substrate. The validity of this assumption was strengthened by periodic observations which indicated that the density of eggs on depositional surfaces was equivalent to the density

¹ Extracted from a thesis for the Master of Science degree, submitted to the graduate faculty at the University of Maine.

² Fenderson, Carll N. (1953) An investigation of the Branch Lake fisheries with the emphasis on the brown trout, *Salmo trutta*. Thesis, University of Maine, Orono, Maine.

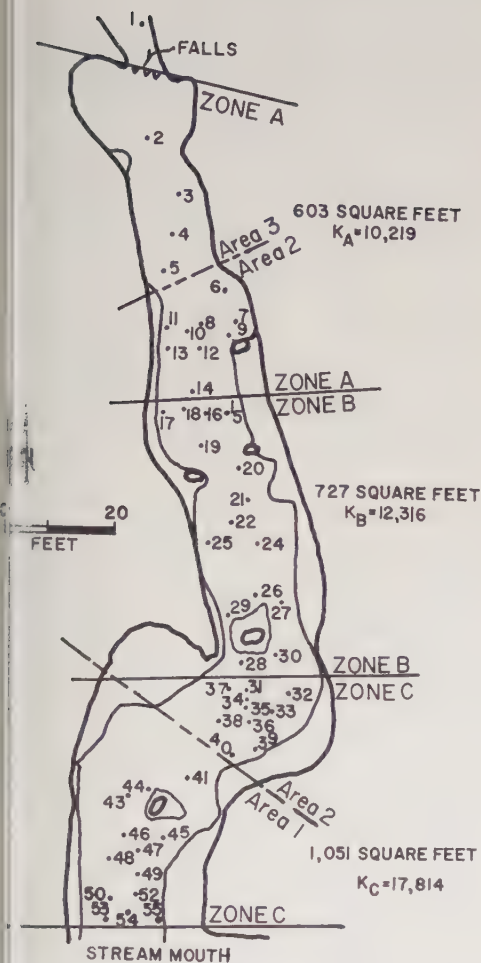


FIGURE 1.—Dean Brook spawning area showing sampling stations, sampling areas, sampling zones, Area 1, Area 2, and Area 3. Increased water levels, which occurred during spawning, are drawn in heavy outline; normal levels are drawn in light outline.

eggs on portions of the stream bed immediately surrounding the sampling units. Secondly, it was assumed that both egg depositional surfaces on each unit were equally available for egg deposition. This assumption was examined by counting the eggs on both surfaces of each unit following the first heavy spawning on the night of April 19. Egg counts on both surfaces of each unit were submitted to chi-square analysis, and there was no evidence to reject the hypothesis of homogeneity ($\chi^2 = 38.7411$ with 35 d.f.) over surfaces of 15 units. The hypothesis of equal egg deposition on both surfaces of each unit was also rejected ($\chi^2 = 0.1287$ with 1 d.f.). One surface on each sampling unit was

designated as the temporary surface. The nightly deposition of eggs on the temporary surface was enumerated daily and then the eggs were destroyed, leaving a fresh depositional surface for the succeeding night's spawning. Samples of total egg density were obtained when the density of eggs per night was summed for all nights of the spawning run. The second surface on each unit was designated as the permanent surface on which eggs were allowed to accumulate, exposed to the environment, until just before the hatching period. The number of viable eggs remaining on the permanent depositional surface is a sample of egg survival.

Suspected large variability in egg densities suggested that a maximum number of sampling units be used. Approximately 2 hours were available daily for checking the sampling units. Since trials performed the previous fall indicated that 55 sampling units could be checked during this time, that number was originally incorporated in the experiments.

The placement of sampling units was in part based on qualitative observations of egg densities made during the 1957 smelt spawning run at Dean Brook which indicated three areas that differed in density of smelt egg deposition (Figure 1). In 1957 area 2 had the greatest density of smelt egg deposition. Areas 1 and 3 had less dense depositions as the distance within these areas increased from area 2. The placement of sampling units within the sampling areas was therefore stratified. Fifteen sampling units were allotted to area 1, 25 to area 2, 4 to area 3, and 1 was placed above the observed limits of previous spawning as an experimental check. The location and assigned number of sampling stations within these areas is shown in Figure 1.

Each sampling station was marked by a steel rod 3 feet long and $\frac{3}{8}$ inch in diameter driven into the stream bottom. A canvas tag bearing the sampling station number was affixed to the top of each rod. Enumeration of smelt eggs adhering to the temporary sampling surfaces was made early each morning. Sampling units were carefully lifted from the water either by hand or with an ice-fishing skimmer, and the eggs on the temporary surface of the unit were counted and destroyed. Following this operation, units were replaced in their original position on the stream bottom.

When eggs were too numerous to count in the field, the canvas strip bearing the eggs was removed from the sampling unit tile, wrapped in cheesecloth, and placed in 10 percent for-

malin for subsequent laboratory enumeration. The canvas bearing the eggs was replaced on the sampling unit by a new strip. Care was exercised during these manipulations to prevent eggs on the permanent side of the unit from becoming injured or dislodged.

Information drawn from sampling units was subjected to variable sources of error. In some cases attachment of eggs to the unit was hindered by silt deposition on the sample surfaces. Silt was washed into the stream during periods of high water and also was displaced by smelt fishermen who agitated bottom materials with their dipnets. Some sampling units were overturned by dipnets. Inversion of a sampling unit caused the surfaces of the unit to be only partially available to egg deposition during the spawning night and also may have permitted physical damage to the eggs on the sampling surface.

A few sampling units were lost as a result of the actions of smelt fishermen and some were completely covered with silt and debris. The discarding of data from error-involved sampling units was considered. Fourteen units were turned over and 45 units were silt-covered in 1,045 chances of unit error. Error from silted-over units was not considered serious since it was assumed that the same number of eggs adhered to the unit as would stick to the natural substrate. The number of units that turned over were very small in proportion to the total and hence data from them was retained. Only units which were lost (15, 23, 34, 42, 51) were eliminated from further analysis.

EGG PRODUCTION AND EGG SURVIVAL

Egg production is considered as the number of eggs deposited in a given area by a spawning aggregation of fish. Egg survival is the viable eggs which result from a given egg production. Graham (1956: 221-223) discusses the history and methods of egg production studies. These studies are predicated upon the obtaining of samples of egg densities which are used to estimate egg production. McKenzie (1947) determined smelt egg densities and survival in spawning pens. Studies of egg production and survival for a spawning stream have not been reported.

Inferences concerning egg production and egg survival were based on data contained in Table 1. Distance in feet of each sampling unit from the stream mouth was determined from a map of Dean Brook (Figure 1). Cumulative density of smelt eggs was considered

TABLE 1.—Distance of sampling units, in feet, at the stream mouth, cumulative smelt egg density, temporary portions of sampling units, actual survival per sampling unit, and percentage survival per sampling unit during the 1958 smelt spawn run at Dean Brook

Unit number	Distance above mouth (feet)	Cumulative density of eggs	Survival	
			Number	Percent
2	133	515	125	24
3	124	1,232	247	20
4	119	1,231	120	10
5	114	393	*	*
6	109	216	13	6
7	105	1,036	177	17
8	105	492	79	16
9	103	802	253	32
10	105	1,185	337	28
11	105	949	548	58
12	102	769	120	16
13	102	496	91	18
14	96	665	163	25
16	93	634	99	16
17	95	378	*	*
18	94	676	342	51
19	89	464	140	30
20	84	437	*	*
21	79	96	18	19
22	77	524	*	*
24	73	325	203	62
25	75	330	86	26
26	67	277	*	*
27	65	162	16	10
28	54	140	20	14
29	64	241	*	*
30	58	143	69	48
31	50	103	0	0
32	58	185	*	*
33	50	216	*	*
35	49	45	0	0
36	46	175	3	2
37	50	78	3	4
38	45	70	0	0
39	44	204	38	18
40	41	204	*	*
41	34	144	6	4
43	30	28	8	29
44	31	105	5	5
45	25	17	*	*
46	24	61	0	0
47	22	45	16	36
48	21	75	30	40
49	19	32	2	6
50	16	102	19	19
52	16	34	0	0
53	12	65	0	0
54	10	1	0	0
55	5	29	0	0
—	—	16,826	3,396	24±

* Survival observations not made.

as the nightly depositions of eggs on the temporary portions of the sampling units summed over all nights of the run. Actual egg survival was the number of eggs remaining on the permanent portion of the sampling unit just before hatching; relative survival was considered to be the percentage of the cumulative density of eggs which survived. Thirteen sampling units of the original 49 were used in survival studies (Table 1).

Egg density and distance above stream mouth

Regression analysis of the cumulative density of smelt eggs on the temporary portion

sampling units and distance of the units from the stream mouth (Table 1) indicates that distance in feet above the stream mouth accounts for 65 percent of the total variation, the distance in feet above the stream mouth combined with its square accounts for 69 percent of the total variation. The regression of the effect of distance in feet above the stream mouth is highly significant ($F = 95.99$ with 46 d.f.) and the regression of distance in feet above the stream mouth squared is significant ($F = 4.64$ with 46 d.f.). A parabolic regression was used to describe the data since it more closely agrees with empirical observations than a linear function. The egg density-distance above stream mouth relation is expressed by:

$$Y = 3.568 + 0.653X_1 + 0.054X_2$$

where Y is the number of smelt eggs per temporary portion of the sampling unit, X_1 is the distance of the sampling unit in feet from the stream mouth, and X_2 is the square of X_1 .

The regression of egg density on distance above the stream mouth implies uniform increase in egg density with increasing distance above the stream mouth and would therefore suggest the lack of well-defined spawning areas. Since there was considerable variation in egg density between the upper and lower portions of spawning, the creation of three zones, A, B, and C, was considered justified for the reduction of sampling error in the estimate of the egg population. Zones differ in the densities of smelt eggs found within them, and their limits are different from the previously described "areas" of spawning. The change from "areas" to "zones" was necessitated by different locations of egg deposition in 1957 and 1959, which suggests that location of egg deposition may vary between years. This is, in this case, attributed to the flood conditions which decreased water velocities in the stream by back flooding from the lake. Decreased water velocities allowed spawning fish to ascend easily to the falls indicated in Figure 1 where they deposited large numbers of eggs in an area where, according to observations made in 1957, minimal spawning was expected.

The greater variability in the egg density-distance data (Table 1) with increased distance above the stream mouth may be caused by increased variation in current velocities in the upstream portion of the spawning area. There are wider variations in the amount of water flowing over closely approximated areas

TABLE 2.—Number of eggs deposited on temporary portions of sampling units per zone and statistics leading to sampling error computed for the 1958 smelt run at Dean Brook

Item	Zone A	Zone B	Zone C
Σ of eggs	9,981	4,827	2,018
$\bar{x}$	767.78	344.78	91.73
s^2	11,495.5	34,092.4	4,109.0
Percent sampling error ¹	27	31	32

$$^1 \text{Percent sampling error} = \frac{t_{.05} s_{\bar{x}}}{\bar{x}} \cdot 100$$

in the upper portions of the spawning area than in lower portions of the spawning area. Areas over which the greatest amount of water passes are more available to egg deposition because more water can carry more eggs over a given area per unit of time. It follows that as the number of eggs increases in an area of large current variation, the variation in densities of eggs in closely approximated areas will also increase.

Estimate of egg production

The number of eggs per zone and statistics leading to the sampling error of the zone means and egg production estimates, are presented in Table 2. The estimate of the egg production in Dean Brook follows methods of representative but disproportional sampling outlined by Schumacher and Chapman (1954: 67-70b). The initial procedure in making an estimate of the egg population is the calculation of a K constant for each zone. The K constant is determined by dividing the area of each zone, ascertained by planimetry of Figure 1, by the area of a single sample surface ($K_A = 10,219$; $K_B = 12,316$; $K_C = 17,814$). Calculations for estimates of the zone egg populations are the product of the mean number of eggs deposited on the temporary portions of the sampling units and the K constant. The zone estimates were summed and provided an estimate of 13,726,351 smelt eggs for the 1958 spawning run at Dean Brook.

To obtain an estimate of the variance of the total egg population, the variance of the mean of each zone was multiplied by the number of samples in each zone to provide an estimate of variance for the number of eggs on the sampling units within each zone. The estimate of the variance of the egg population estimate in each zone was obtained by multiplying the variance of the sum of eggs per sampling units within a zone by the K constant squared for that zone. The sum of the zone variances is the estimate of the variance for the total egg population. The standard error

TABLE 3.—*Survival of smelt eggs in each zone during the 1958 smelt spawning run at Dean Brook and statistics leading to the sampling error of the egg estimates*

Item	Zone A	Zone B	Zone C
Σ of eggs	2,273	993	130
$\bar{x}$	189.42	110.33	7.22
s^2	20,487.36	11,393.75	127.60
Percent sampling error ¹	48	74	18

$$^1 \text{Percent sampling error} = \frac{t_{.05} \quad s_{\bar{x}}}{\bar{x}} \cdot 100$$

of the estimate of the egg population was 3,525,971.

Relation of egg survival to distance above stream mouth

Actual egg survival and distance of the sampling unit from the stream mouth were submitted to standard regression techniques. Analysis of variance of the regression components showed a highly significant F ratio ($F = 26.42$ with 36 d.f.) for the regression of distance in feet above the stream mouth, and no significance ($F = 1.601$ with 36 d.f.) of the regression of distance in feet above the stream mouth squared, thus eliminating consideration of a curvilinear description of the data. Distance in feet above the stream mouth accounts for 42 percent of the total variation. These data demonstrate a trend of increased numbers of surviving eggs with increased distance above the stream mouth. The linear regression of egg survival–distance of eggs above the stream mouth is:

$$Y = 47.89 + 2.09X$$

where Y is egg survival and X is distance in feet above the stream mouth.

Actual egg survival–distance data presented in Table 1 suggest that covariates used in regression calculations of egg survival–distance form a peak in egg survival at about 105 feet above the stream mouth. If the number of viable eggs is actually greater in the 105-foot area than above or below this area, as is indicated by the minimal samples, there would then exist at this peak of survival a corresponding density of eggs deposited that would be optimum for the production of the greatest number of egg survivors. Solving the equation for egg density at 105 feet indicates that there would be roughly 80 eggs per square inch or 11,475 eggs per square foot in the region of optimum egg density.

Relative egg survival was not correlated with distance above the stream mouth apparently

TABLE 4.—*Relative smelt egg survival in Dean Brook subsequent to 1958 spawning run*

Zone	Mean egg production per square foot	Mean age survival per square foot	Percent egg survival per square foot
A	13,007	3,210	24
B	5,841	1,863	32
C	1,555	122	8

because environmental variables which operate differentially in small spatial areas cause variation in egg mortality between sampling units.

Estimate of egg survival

The mean relative egg survival (Table 4) was estimated to be 24 percent. Since the data were derived from eggs collected to May 15, which was from 1 to 15 days before hatching, the percentage of survival is high. The estimate of egg survival utilized same of actual survival (Table 1) analyzed in the same manner as egg density (Table 3). The large sampling error is attributed to the small number of highly variable samples. Estimated egg survival was 3,423,177, with a standard error of 610,384.

Relation of egg survival to egg production

As indicated by the regression analyses, egg survival and egg production both increase with distance above the stream mouth. Further exploration of this relationship was made by comparisons of egg production and egg survival in each zone. Mean egg production per square foot in each zone was estimated from totals per zone divided by the area of the zone (Table 4).

It is apparent that increased egg deposition results in increased survival. Since a greater percentage of survival is found in zone B, it is assumed that more favorable densities of egg deposition are found in this zone. The comparatively low percentage survival in zone C can be partially attributed to variables influenced by increased egg densities. The low percentage survival in zone C seems related to the fact that the eggs in this zone were probably spawned earlier in the run and were exposed to the environment for a greater length of time than were those spawned later. Consequently, eggs spawned earlier in the run are more susceptible to the effects of environmental variables. It is suggested that time has a greater influence on egg mortality than does density.

Table 5.—Total number of smelt eggs deposited on temporary portions of sampling units during each night of the 1958 smelt spawning run at Dean Brook, and some environmental variables on these nights

Night	Index of spawning activity (Number of smelt eggs)	Light	Fishing intensity	Hours after sunset when smelt first observed	Numbers of fish observed	Stream temperatures (degrees F.)	
						Maximum	Minimum
April 17	27	Dark	None	1.5	Several dozen	44	39
April 18	4	Dark	Light	0.0	Less than previous night	44	40
April 19	311	Dark	None	0.0	Moderate	46	41
April 20	418	Dark	Light	1.0	Moderate	43	40
April 21	420	Dark	Moderate	1.0	—	46	42
April 22	1,951	Dark	Heavy	—	More numerous	44	44
April 23	2,808	Dark	Light	0.75	Peak numbers	45	44
April 24	1,409	Dark	Very heavy	—	Less than previous night	50	44
April 25	413	Bright moonlight	Heaviest	1.0	Less than previous night	51	47
April 26	1,236	Dark	Moderate	1.25	Light	47	45
April 27	5,289	Bright moonlight to dim	Heavy	3.5	More than previous night	46	43
April 28	550	Dark	None	3.0	Few	42	40
April 29	322	Dark	Light	—	Few	43	40
April 30	304	Bright moonlight	Light	—	Few	47	43
	1,342	Very bright moonlight	None	3.0	—	47	41
	22	Bright moonlight	None	—	None observed	48	42

INDEX OF SPAWNING ACTIVITY

It is assumed that the total number of eggs deposited on the temporary portions of the sampling units per night reflects the intensity of spawning and can, therefore, be considered an index of spawning activity. Relations between environmental variables and spawning activity (Table 5) were examined. Peaks in spawning activity occurred on both bright and dark nights. The night of greatest spawning activity, April 27, was also a night of high fishing intensity. On the following night, April 28, there was no fishing disturbance yet the eggs deposited on the sampling units were roughly 10 percent of those deposited on the previous night, which indicated that heavy egg deposition is not necessarily interrupted by stream disturbance. There may have been greater egg deposition on April 27 if there had been no disturbance, but it is evident that heavy deposition can occur during dark nights when there is considerable stream disturbance. Peak numbers of smelts in the stream did not parallel peak egg depositions. Maximum and minimum temperatures occurring in the stream during the run were not related to spawning activity. There was no consistent relation between time of appearance of smelts on each spawning night and the number of eggs deposited.

PROLARVAL PRODUCTION

Prolarval production of smelt was decreased by variables that either limited egg production or increased egg mortality. Egg production was reduced by smelt fishermen who captured females that had not spawned their full complement of eggs. Observations at Dean Brook compared with those of Creaser (1925) and

Hoover (1936) which indicate the presence of small numbers of smelt eggs in the stomachs of spawning smelts, the ingested eggs obviously not entering egg production. Egg production was also limited by eggs washing from the stream and the possibility of non-fertilization.

Egg mortality seemed to be associated with several observed variables. Dead eggs were first noticed during periods of relatively extreme daily water temperature fluctuations (as much as 7° F.). Physical damage to eggs was apparent where habitat was disturbed by smelt fishermen. Some eggs were covered with bottom materials after freshets. Eggs deposited in shallow water were exposed when water levels fell near the end of the hatching period. After the 1957 spawning run, Rupp reported³ apparent egg predation by larval and nymphal insects. Leeches (Erpobdellidae) appeared to feed on smelt eggs. Fungus which covered most of the egg masses did not seem to be a primary factor in egg mortality *per se* but rather its mycelia entrapped hatching smelt prolarvae and prevented their escape from the egg mass.

An estimate of prolarval production was made by placing five no. 38 mesh nylon plankton nets in the cross-sectional area of the stream mouth. The numbers of prolarvae in the nets were counted daily and multiplied by the area of the cross section divided by the area of the plankton net mouths. Daily prolarval production was summed and a total production for the entire spawning run was estimated to be 75,440. This production is close to 0.5 percent of the total egg production and

³ Rupp, Robert. Dingell-Johnson Job Completion Report, Maine, F-10-R-3, Job II.

2 percent of the egg survival. The average production per square foot of Dean Brook spawning area was 5,762 eggs and 32 pro-larvae.

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Use of Radioisotopes in Hydrobiology and Fish Culture

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ABSTRACT

Use of radioisotopes has increased rapidly in hydrobiology and fish culture. Their use, especially P^{32} , to study circulation of nutrients has been demonstrated and offers opportunities in problems of lake metabolism. The most extensive use of isotopes has been to determine photosynthetic activity in plankton through C^{14} uptake. Applications and limitations are discussed. Isotopes have been successfully used in food studies of fish to determine food selection, metabolism, and storage. Water movements in fresh and salt water and in sewage problems have been successfully followed by use of various isotopes. Marking of aquatic animals with radioisotopes has many possible applications, but has been little used because of some inherent problems related to danger to organisms and in field use. Extent of future use of isotopes in hydrobiology will be determined by further study of hazards and public acceptance of field studies.

Many useful applications of radioisotopes have been made during the past decade in medicine, industry, and in basic science. This report reviews recent research in hydrobiology and fish culture in which radioisotopes have been used. The growing list of subjects that have been investigated with radioactive tracers has led the authors to feel that such a report is timely. It has been prepared to acquaint workers with new research possibilities that have arisen as radioactive materials have become available.

An attempt will be made to summarize the rather extensive literature dealing with the biological effects of fallout and radioactive wastes released into rivers at reactor sites. Many of these studies have provided useful biological data, but they have been primarily concerned with the evaluation of hazards rather than with exploring new avenues of scientific interest. Readers are referred to a recent bibliography compiled by Klement and Ben (1960) for references in this field. Radioisotopes have been employed in almost every field of biological research. Within the fields of hydrobiology and fish culture the principal areas of research in which isotopes have been used are: (1) chemical cycles in lakes and ponds; (2) productivity measurements; (3) food relationships; (4) fish diseases and fish nutrition; (5) tracing movements of water, pollutants, and sediments; and (6) marking aquatic animals.

Several other review articles dealing with the use of isotopes have proven helpful in the

preparation of the present report. Of particular interest is the paper of Zhadin, Kuznetsov, and Timofeev-Resovsky (1958) which summarizes in considerable detail hydrobiological studies which have used isotopes in the U.S.S.R. and the lectures given at the symposium on *Marine Biological Applications of Radio-Isotope Research Techniques* in Naples during September 1957. These lectures have been published as a supplement to volume 31 of the Publications of the Zoological Station of Naples. The reviews of Griffin (1952) and Pendleton (1956) summarize earlier studies, particularly those concerned with marking animals with isotopes.

CHEMICAL CYCLES IN LAKES AND PONDS

Significant contributions to the understanding of the biological pathways nutrients and chemicals take in lakes and ponds have been made by adding radioactive tracers to the water. Radioactive phosphorus (P^{32}) has been most widely used, because its short half-life makes it relatively safe in field experiments and because it is a nutrient element which is taken up rapidly by bacteria and plants and soon appears in almost every form of life. Readers are referred to a recent and excellent review of this subject by Foster (1959).

With P^{32} Hutchinson and Bowen (1950) demonstrated that phosphorus was continually passing from the epilimnion to the hypolimnion of stratified lakes through the sedimentation of seston. Two treatments of Nova Scotian lakes with P^{32} by Hayes and co-workers (Coffin, Hayes, Jodrey, and White-

¹Portland, New York.
²Seetown, West Virginia.

way, 1949; Hayes, McCarter, Cameron, and Livingstone, 1952; Hayes and Phillips, 1958) led to some interesting observations on the movement of phosphorus in lakes. These authors showed that phosphorus atoms are continually and rapidly exchanged between the lake water and other forms of solids in the lake system (e.g., mud, plankton, bacteria, rooted plants). The disappearance of P^{32} from the water of a lake was found to be similar to the disappearance of P^{32} and other tracers in biological systems studied in the laboratory. From data on the rate of disappearance, calculations can be made of the turnover time, which is the time it takes phosphorus atoms to move through the "solids" of the lake and reappear in the lake water. Hayes *et al.* (1952) also recognized the similarity between the manner in which P^{32} disappears from lake water and the manner in which natural phosphorus is lost from water after a lake or pond is fertilized with inorganic phosphorus. Phosphorus added as a fertilizer appears to act like P^{32} and must equilibrate with phosphorus in the "solids." Soon after fertilizer is added, therefore, the phosphorus content of the water falls to a level only slightly higher than before fertilization.

A similar study with P^{32} by Rigler (1956) in Toussaint Lake in Ontario verified many of the findings in the Nova Scotian waters and also emphasized the importance of planktonic bacteria in the turnover of phosphate. Recently Pomeroy (1960) published the turnover rates of dissolved phosphorus in a variety of natural waters. These figures suggest that short residence times of phosphorus are indicative of depleted phosphate and/or high metabolic activity. Zhadin, Kuznetsov, and Timofeev-Resovsky (1958) report studies in the U.S.S.R. in which P^{32} and Ca^{45} have been used in experiments on the fertilization of fish ponds. The experiments have demonstrated advantages in using a combined mineral fertilizer rather than one containing only phosphorus.

With P^{32} Rice (1953) studied the exchange of phosphorus between cells of the diatom *Nitzschia* and the medium. He found that in time diatom cells will convert some of the exchangeable phosphorus into organic compounds in which it is nonexchangeable.

Zicker, Berger, and Hasler (1956) were able to determine the depth from which phosphorus can be released into the water from lake bottom soils by using P^{32} . They found

that virtually no phosphorus was released without stirring or agitation from a depth greater than one-quarter inch below the surface.

Much less use has been made of elements other than phosphorus in studying movement of materials in lakes. Likens and Hall (1960) added radioactive sodium (Na^{24}) to the bottom water of a small meromictic lake and studied its horizontal and vertical movement. Using radioactive sulphur (S^{35}) Suwara, Koyama, and Noda (1954) obtained evidence that ferric hydroxide flock sorbs sulphate ion and carries it to the lake bottom. Zhadin, Kuznetsov, and Timofeev-Resovsky (1958) reviewed the studies of Ivanov who used isotopes to study the processes of phosphate reduction and sulphide oxidation in lakes. He found that sulphate reduction occurs chiefly in the surface layers of bottom deposits and that the surface layer of Onyonoye Lake produces H_2S at the rate of 0.5 milligrams per liter per day.

The foregoing studies are examples of how radioisotopes may be used to learn more about the chemical cycles of natural waters. Possible applications of isotopes in studies of this type are far from being exhausted. Many interesting problems suggest themselves. Radioactive iron (Fe^{59}) with a half-life of 45 days could be used to investigate the iron cycle and some of the complex relationships between iron and the organic substances in lake water. Radioactive cobalt (Co^{58}), which has a half-life of 72 days, might be used to study vitamin B_{12} and its translocation in aquatic habitats. The possibility of labeling organic compounds should not be overlooked. Many of the herbicides and pesticides which now find their way into natural waters can be labeled and in this way traced through the food chain. Thus we have at hand a means of investigating the effects of these substances upon aquatic life with more precision than hitherto possible.

PRODUCTIVITY MEASUREMENTS

The isotope most widely used at the present time in hydrobiological studies is carbon-14. Its principal use is to measure the uptake and fixation of carbon by phytoplankton. From such measurements it is possible to calculate an estimate of the rate at which the phytoplankton in the ocean, a lake, or a pond are producing organic matter.

Technique

The techniques used by various investigators have differed in details, some of which may be unimportant. Recent studies, however, have indicated that certain seemingly minor differences in technique lead to sizeable differences in results. Perhaps the most useful reference on technique and one which includes a discussion of reliability and inherent errors, is the paper by Doty and Oguri (1958).

Water samples are collected from the sea or lake surface or at any depth at which photosynthesis measurements are desired. In lake studies ordinarily enough depths are sampled to give a profile through the photosynthetic zone (surface to a depth at which less than 1 percent of surface light remains). The type of sampling bottle used seems to influence the photosynthetic rates that are obtained in lake studies (Doty and Oguri, 1958). Three amber-glass, pyrex bottles of 250-milliliter capacity are filled from samples collected at each depth. Two of the bottles are used as "light" bottles and the third serves as a "dark" bottle. The dark bottle is either wrapped with heavy aluminum foil or covered with opaque tape or black paint to exclude light. One ampoule of radioactive carbonate solution of known activity is introduced into each bottle. The ampoule is then rinsed and the rinse water added to the bottle. In lake studies the bottles are incubated in the lake at the depth at which they were collected. In oceanographic studies samples are sometimes incubated in a box under controlled light conditions and at sea surface temperature (Doty and Oguri, 1958). The incubation period usually used is between 2 and 8 hours. After incubation, samples are removed from the lake incubator and filtered through a Millipore filter disc of HA porosity. The filter disc is washed with 20 milliliters 0.001 N HCl, removed from the filter holder, and stored for counting. Since the isotope has a long half-life, counting can be delayed indefinitely. The foregoing part of the procedure can be carried out in the field by trained technicians. Once a reliable procedure has been established, the work does not presuppose any expert knowledge.

Counting and calculations of carbon fixation rates can be carried out by the investigator if equipment is available, or planchets can be mailed to the Central Agency for C^{14} determination at Charlottenlund Slot, Denmark, for counting and calculations (see below). A

windowless gas-flow type counter is preferred for counting but a thin window Geiger-Müller counter can be used. Samples are usually counted for from 3 to 10 minutes, depending upon their activity. If a calculator is used, an operator can complete all the necessary calculations while samples are being counted.

Materials

The ampoules containing radioactive sodium carbonate solution must be carefully prepared. Their activity must be accurately known. Ordinarily they are made up so as to contain between 2 and 4 microcuries of C^{14} . Ampoules may be prepared from solid barium carbonate purchased from the Oak Ridge National Laboratory or from a number of concerns handling radioactive chemicals. Several companies will on order furnish ampoules containing the desired activity.

In 1958 UNESCO funds were provided for the establishment of a central agency for C^{14} determinations at Charlottenlund Slot, Denmark.³ This agency was organized to provide standardized C^{14} ampoules, to count C^{14} samples, and to calculate carbon assimilation rates. It operates on a nonprofit basis and its services are available to all scientific organizations in the world. An organization can purchase either the standard ampoules alone or at a slightly higher cost can secure the counting and calculation services (numbered membrane filters are furnished as a part of the counting services). Water sampling and filtering equipment can also be purchased from this agency.

Applications

Widespread use of this technique in oceanographic studies (Steeemann Nielsen, 1952; Doty and Oguri, 1957; Ryther and Yentsch, 1958) has been followed by somewhat more limited use in fresh water (Nygaard, 1955; Frey and Stahl, 1958; Rhode, Vollenweider, and Nauwerck, 1960). Although the method measures photosynthetic processes within the confines of a bottle and therefore is only an approximation of this phenomena in nature, it appears to give a reliable index of production rates that can be used to compare one situation with another. Since there are still some unanswered questions concerning the interpretation of results in terms of the production by the plant cell, C^{14} data are best used in a relative rather than an absolute

³ *Limnol. and Oceanogr.*, 4(1): 106-107.

sense (cf. Rhode, Vollenweider, and Nauwerck, 1960).

Suspension of bottles in a lake at a variety of depths enables one to obtain a rather complete photosynthetic profile for the entire basin. Counting of phytoplankton for a comparable series of depths would be laborious and at best would give a static measurement of the phytoplankton crop, not phytoplankton production. The C^{14} technique on the other hand makes only modest demands upon manpower while providing a useful assessment of primary productivity. Since the field work does not require expert knowledge, it can be made a part of routine inventories on lakes and ponds.

Special applications of the technique have been made by certain investigators. Schelske⁴ studied the influence of various combinations of nutrients and chelating agents upon photosynthesis in a marl lake by comparing the C^{14} fixation rates in bottles of lake water to which nutrients and chelate had been added with control bottles containing no additives. Photosynthetic rates were determined by the C^{14} method after the bottles had been incubated in the lake for a 7- to 10-day period. A similar use of the method was made by Goldman (1960) who tested the effectiveness of various nutrients upon the waters of Alaskan lakes by measuring C^{14} uptake rates after the incubation of algal cultures in the lake.

With the exception of these two studies, as yet the method has not been used to evaluate changes in production rates of lakes and ponds resulting from the addition of fertilizers and other chemicals. This would appear to be a promising application in the field of fisheries biology.

FOOD RELATIONSHIPS

Isotopes have been used in several different types of studies dealing with the feeding of aquatic animals and the food chains of aquatic communities. The manner in which radioisotopes pass through an aquatic food chain has been studied by Davis and Foster (1958). These authors followed the uptake by the invertebrate and fish fauna of a variety of radioactive waste materials from the Columbia River. They found that both adsorption and

absorption are of major importance in the uptake of radioisotopes by plants, but that animals secure almost all of their radioactivity by ingestion of food. The concentration of radioactive substances in animals was found to vary between species, and fluctuated according to food habits and type of life cycle. They believe that in a flowing stream the specific activity of an isotope diminishes along the food chain.

A variety of invertebrates have been labeled with isotopes and then used in feeding experiments (cf. papers cited below by Shekhanov, 1955; Tomiyama *et al.*, 1956; Kobayashi *et al.*, 1960). Trama⁵ fed mayflies (*Stenonema*) algae labeled with P^{32} . Upon obtaining measurements of respiration and assimilation he was able to calculate the efficiency with which this herbivore converts food into living matter. Sorokin (reported by Zhadov, Kuznetsov, and Timofeev-Resovsky, 1958) used algae and bacteria labeled with C^{14} to study the nutrition of cladocera and tentacled larvae. These studies showed that midge larvae assimilate bacteria and blue-green algae and that cladocera assimilate bacteria and protococcus algae.

Pendleton and Smart (1954) labeled amphipods (*Hyalella*), ostracods (*Herpicyprina*) and mosquito larvae (*Aedes*) with P^{32} . They introduced these labeled invertebrates into aquaria containing adults and fry of the leucichthys (*Iotichthys phlegethontis*). The chub soon showed some radioactivity indicating that these three arthropods had been used as food. Nelson⁶ studied the rate at which trout took up the radioactive phosphorus added to the water of an alpine lake in Colorado. He found that rainbow trout took up the isotope twice as fast as brook trout. He also noted that brook trout which had spawned in the lake took up the isotope about twice as fast as planted trout. Nelson believed these differences in uptake rates were due to differences in feeding and food habits.

Chipman (1959) has reviewed studies in which isotopes have been used to investigate foods and feeding activities of marine animals. An excellent example of studies of this type is the work of Rice and Smith (1958). The

⁵ Trama, Francesco B. (1957) The transformation of energy by an aquatic herbivore *Stenonema phlegethontis* (Ephemeroptera). Univ. of Michigan thesis, 80 pp.

⁶ Nelson, Wesley C. (1958) The uptake of phosphorus P^{32} by the fish population. Progr. Rept., U. S. Atomic Energy Comm., Proj. No. AT-(11-1)-390.

⁴ Schelske, Claire L. (1960) Preliminary report on the influence of iron, organic matter and other factors upon primary production of a marl lake. Inst. Fish. Res., Mich. Dept. Conservation, Rept. 1586 (unpublished).

workers fed phytoplankton labeled with P^{32} to the hard clam (*Venus mercenaria*) and by measuring the rate of disappearance of the phytoplankton cells were able to calculate the clam's filtering rate. Using this technique they were able to study the influences of a number of environmental factors upon filtering rates.

FISH DISEASES AND FISH NUTRITION

Ionizing radiation is used on a large scale in medicine. The earliest application was only for diagnostic purposes and therapy. The discovery of radium was next, and the most recent is the use of radioactive isotopes of many elements in diagnosis and therapy of various diseases. Rosenthal (1958) studied the uptake of calcium⁴⁵ and strontium⁹⁰ by guppies and an aberrant strain of guppies characterized by hereditary lordosis. Fish affected by this abnormality take up less Ca^{45} and contain it in larger quantity in the bones than the normal wild guppies.

Roche and Leblond (1954) used iodine¹³¹ to destroy the diffuse thyroid tissue of the Atlantic salmon (*Salmo salar*). This destruction is effected by the selective uptake of iodine by the thyroid gland. Though the work has been done from the physiological approach, this method may offer a procedure of therapy for carcinoma of the thyroid such as was described by Gaylord and Marsh (1912).

McCay *et al.* (1936) established, through bioanalyses, that rapidly growing trout utilized dissolved as well as dietary calcium. It is probable that dissolved minerals could be an important source to fresh-water fish was shown by Wolf (1951), who raised trout on a "mineral-free" diet. Because of his synthetic diet. Because there is no confounding of mineral sources (food and water), little advancement in mineral nutrition of fish could be made using standard methods. The production and availability of radioisotopes and the development of tagging techniques for labeling and tracing minerals from specific sources provided a potent research tool. As yet, the major efforts have been applied to this field of mineral nutrition with practically no emphasis on the organic nutrients.

That contamination of fresh waters with radioactive wastes from atomic energy installations could cause selective concentration of radioactive materials in fish populations, either by the fish ingesting contaminated food or by direct uptake, was early recognized and

investigated (Prosser *et al.*⁷; Higgins, 1950; Krumholz, 1956). Both the hard and soft tissues of aquatic organisms were found to concentrate radioactive ions.

Laboratory tracer experiments have been carried out under simulated natural conditions to investigate the metabolism of minerals. Since many of the natural foods of fish are excellent concentrators of minerals, it is possible to rear them in a suitable radioactive environment and then use the organism as labeled food. This method has been used with a variety of organisms, including *Daphnia* (Shekhanova, 1955), the sludge worm *Rhizodrilus* (Tomiyama *et al.*, 1956), and *Chironomus* larvae (Kudriavtzev and Pora, 1958). After *ad libitum* feeding, it is possible to measure the utilization and excretion by the fish of the particular nutrients formed from the radioisotope by the food organism. Kobayashi and Tomiyama (1959) and Kobayashi *et al.* (1960) have extended these studies to include the turnover of labeled phosphorus in *Rhizodrilus* and have determined the distribution of organic phosphorus fractions. Much of the phosphorus was converted to the organic forms.

Because there is uncertainty of the chemical nature of a labeled nutrient following metabolism by intermediate food organisms, and to eliminate *ad libitum* feeding, the Cortland Laboratory (Phillips *et al.*, 1957, 1958, 1959) has investigated the utilization of major and trace dietary minerals by feeding trout quantitatively labeled doses of calcium, phosphorus, and cobalt in capsulated synthetic foods. Concurrently with these diet experiments, this laboratory also prepared various representative synthetic waters and measured a normal direct uptake by trout of the previously-mentioned minerals and in addition chloride and sulphate. Dissolved calcium significantly contributed to structural growth.

TRACING MOVEMENTS OF WATER, POLLUTANTS, AND SEDIMENTS

The high degree of sensitivity with which isotopes can be detected has led to their use by oceanographers, hydrologists, and engineers to study water movements. An example of the extent to which an isotope can be dis-

⁷ Prosser, C. L., W. Pervinsek, J. Arnold, G. Svihla, and P. C. Tompkins. (1945) Accumulation and distribution of radioactive strontium, barium-lanthanum fission mixture and sodium in goldfish. Atomic Energy Comm., MDDC-496.

persed in water and still be detected comes from a report of Ball and Hooper.⁸ A Michigan trout stream was dosed with 1.5 milliliters of radioactive phosphorus (23 millicuries). Before it was added to the stream, this small quantity was diluted with 55 gallons of water and during a period of 30 minutes the mixture was fed at a constant rate into a stream having a flow of 37 cubic feet per second. Even though phosphorus³² is taken up rapidly in the stream, the radioactivity was detected at a downstream location 2½ miles away for a period of over 2 hours. A water activity approximately one trillion times smaller (1×10^{-12}) than the activity of the solution before dilution was counted after the water samples were concentrated.

A review of uses made of isotopes to investigate problems of large-scale ocean circulation and transport has been published (National Academy of Sciences-National Research Council, 1957). Parker (1958) employed tracers to determine the eddy diffusion coefficients in a Massachusetts reservoir. A number of recent papers have discussed the use of isotopes to determine speed and direction of flow of ground water (Finkel' shteyn *et al.*, 1958; von Buttlar and Wendt, 1958; Halevy *et al.*, 1958). Simpson *et al.* (1958) treated sewage from Knolls Atomic Laboratory with 4.53 curies of P³² prior to its discharge in the Mohawk River. They then followed its movement with immersible Geiger-Müller tubes and by sampling. They found that the initial path of the sewage was strongly influenced by differences in density due to temperature. During the warm months cold sewage moved on the river bottom perpendicular to the river currents for the first 800 feet of travel. During cold months sewage rose to the surface and at times was moved upstream by wind. Near freezing the sewage first rose and then sank as its temperature approached 39° F.

MARKING AQUATIC ANIMALS

The marking of animals with radioisotopes is a rather obvious application of nuclear technology to ecological and systematic studies which has been frequently discussed in the literature but has found comparatively little use in aquatic biology. Isotopes have been

widely used in the field of entomology for population studies, analysis of insect dispersion, transmission of disease, and insect control with insecticides (Jenkins, 1951). Pendleton (1956) and Griffin (1952) present discussions of the advantages and limitations encountered in marking animals with radioisotopes. These papers may also be consulted for details concerning isotopes that have been used and the dosages carried on radioactive tags.

Seymour (1958) has discussed the tagging of fish with radioisotopes. His paper should be consulted for a review of the regulations governing use of isotopes which would apply to a fish-tagging experiment. Seymour concludes that methods now in use for marking fish are generally more practical than isotopic methods. There are four general limitations that would be encountered in tagging aquatic animals. First, penetration of radioisotopes through water is poor. The shielding effect is so great that an aquatic animal could not be detected through more than a few feet of water, even though it was carrying a strong emitting energetic gamma radiations. Second, tags of high energy gamma radiation might, despite shielding, kill or disable the animal so that it does not behave as other members of the population. Thus it would be impractical that a study be made of the influence of the tag upon the fish before an isotope tag could be used in a population study. Third, a possible advantage of radioactive tags over other fish tags is that it may be possible to tag fish with an isotope tag at the egg or fry stage and follow their survival a number of years. Such a use would require an isotope of a long half-life. Fish carrying a radioactive tag with a long half-life may turn present a serious health hazard depending upon the manner of tagging, the extent to which the species is used as food, and the likelihood that tagged specimens will be uncovered by the public. Fourth, an isotopic tagging technique which identifies individual groups within a tagged population, has not been worked out. This problem, however, does not seem to be insurmountable, and several possible methods might be employed.

It is clear that situations in which isotopic marking might be used are either those in which there is complete control over the harvest or where the tagged fish can be handled without danger to the public. Remote areas might be used where there is little or no possibility of the isotope tag being

⁸ Ball, R. C., and F. F. Hooper. (1959) Preliminary report on translocation of radioactive phosphorus (P³²) in a Michigan trout stream. Progr. Rept., U. S. Atomic Energy Comm., Div. of Biol. and Med., Contr. No. AT(11-1)-655.

ally ingested by humans. An isotope with short half-life and one which gives off energetic gamma radiation would have the advantage of minimizing the health hazard and at the same time facilitating the detection of marked animals. Such tags, however, would find little use in solving some of the more challenging fish population problems. Townsley, Townsley, and Hiatt (1956) demonstrated that the amount of activity (cesium¹³⁷) within marine fish can be accurately estimated by external monitoring with the probe of a count rate meter. This would eliminate the time-consuming procedure of dissecting and ashing the fish to determine its activity. External monitoring would also allow tabulation of marked individuals without sacrificing members of the population.

P. Scott of the London, Ontario, Research Station of the Fisheries Research Board of Canada has furnished the authors with the following brief summary of some very significant work in progress at this station on the use of radioisotopes for tagging fish:

We simply empirically test the up-take and [from fish] of all gamma-emitting isotopes with half-lives longer than seven days. Any which are found to have a biological half-life longer than seven days would appear on the surface to have potentialities as marks. To date we have not tackled any of the pure beta-emitters but plan to do so in the future.

and his group will soon publish a report on the possibility of using iron⁵⁹ and cesium¹³⁷ as short-term tags.

LICENSING OF ISOTOPES FOR RESEARCH

Licensing procedures and requirements for the use of radioisotopes in the United States are given in part 30, Title 10 Code of Federal Regulations.⁹ This regulation provides for general licenses and specific licenses. It issues a general license to anyone wishing to use quantities of isotopes that do not exceed the limits specified in the regulations. Quantities available under general license are adequate for many purposes. For example, the quantity of C¹⁴ specified under the general licensing procedure is 50 microcuries. The regulation allows as many as 10 such quantities to be on hand at one time. Thus under general license one could possess as much

as 500 microcuries of C¹⁴. If C¹⁴ were to be used in productivity studies, 250 ampoules containing 2 microcuries could be on hand. The use of materials secured under a general license is subject to restrictions set forth in the regulations mentioned above.

Larger quantities can be secured by obtaining a specific license. Many universities and other agencies have a specific license. Application for a specific license must be made to the Atomic Energy Commission. Each application is judged on its own merits. Two important considerations in judging each application are the training and experience of the applicant in using radioactive materials, and the adequacy of protection against radiation hazards. Applicants should specify the maximum amount of material they will have on hand and how it is to be packaged. This may be an important consideration in approval of the application. For C¹⁴ work 2 or 3 millicuries packaged in ampoules containing 2 microcuries would provide an adequate supply of material for a considerable period of field work. Prospective applicants for a specific license should first secure some training and experience in using isotopes and in measuring radioactivity. This can be accomplished either through formal classroom training or by an apprenticeship with a qualified investigator. Experience can be obtained by first using generally licensed quantities.

FUTURE USES OF RADIOISOTOPES IN FISHERIES

Without doubt there will be a greater use of radioisotopes in fisheries laboratories as personnel trained to work with isotopes are recruited into this field. Although radioisotopes can aid researchers in only a small fraction of laboratory research problems, tracers can be extremely effective in many instances, *e.g.*, studying factors affecting the filtering rate of clams as carried out by Rice and Smith (1958). Use of radioactive materials in field studies will continue to be heavily restricted by health hazard considerations. Only those field studies where there is a minimum risk of public exposure will be allowed by the licensing agency. Two conditions might be expected to influence the extent to which isotopes will be licensed for future field investigations: (1) An increase in knowledge of the hazards associated with various types of radiation. Much remains to be learned in this field. Present standards are tentative and will be revised as more facts

become available. (2) The extent to which the public accepts radioactivity as a part of everyday life. The teacher-training program recently started by the U. S. Atomic Energy Commission is a sign of progress toward broadening public understanding of radiation.

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Mortalities of Downstream Migrant Salmon at McNary Dam¹

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ABSTRACT

A 3-year study was conducted to determine mortality rates for downstream migrant salmonids passing through spillways or turbines at McNary Dam. Mortalities were determined by releasing marked fish into the exit under study (spillway or turbine) and marked control groups immediately below the dam. Samples of released fish were recovered at stations below the dam, and survival rates were computed from the ratio of the number of experimental to control recoveries. Detailed techniques were devised to test assumptions involved in the estimating procedure. In 1955 and 1956 estimates were obtained for fingerling chinook salmon (*Oncorhynchus tshawytscha*) at McNary Dam. In 1957 yearling chinook were tested at Big Cliff Dam, a structure on the Santiam River with a turbine and spillway similar to those at McNary Dam. As a control measure, fingerling chinook were also tested in 1957. In all experiments the turbine was the major source of mortality. For each exit, no significant difference was found between mortalities at McNary Dam and Big Cliff Dam on fingerling chinook or between mortality rates for fingerling and yearling chinook. Estimated mortality rate of salmon passing over the spillway was 2 percent with a 95 percent confidence interval from 0 to 4 percent. Estimated mortality of salmon passing through the turbines was 11 percent with a confidence interval from 9 to 13 percent. The consistency of the results of the studies indicated that the estimates were valid representations of the mortalities experienced under the tested conditions.

INTRODUCTION

The Columbia River system is one of the most important salmon- and steelhead-producing areas in the United States. An annual commercial catch of 6 to 8 million pounds of salmon is taken within the river, and a large percentage of offshore salmon catches from Oregon to Alaska is of Columbia River origin. Species involved in the commercial fishery are chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), chum salmon (*O. keta*), and steelhead trout (*Salmo gairdneri*). In addition, the Columbia River and its tributaries support an extensive sport fishery for chinook and coho salmon and steelhead trout. They also contribute measurably to important offshore sport fisheries.

Fishermen and management agencies are concerned over the effects of hydroelectric dams on these salmon and steelhead runs. During the past 25 years, six major dams have been completed on the Columbia River, two are under construction, and four more are in the planning stage. When these dams are completed, a major portion of both upstream and downstream migrant salmon will have migrated over or through 10 dams before

reaching their final destination. When even a single dam is placed in the migrational path of anadromous fish, serious problems arise in passing adults to their spawning grounds without delay, injury, or mortality and passing immature downstream migrants safely to sea.

Because there may be cumulative effects from a series of dams, it becomes important to evaluate their effects on downstream migrant salmon passing over the spillway section or through the turbines. Mortality studies were conducted by the Washington Department of Fisheries on two dams on the Elwha River (Schoeneman and Junge, 1954), but adequate investigations had been made previously for low head, river-run dams of this type found on the Columbia River. In the present work, the methods developed in the Elwha study were extended to evaluate mortalities at McNary Dam which is located in Umatilla, Oregon, approximately 200 miles upriver from Portland, Oregon.

Of primary importance to the work of the first year at McNary Dam (1955) was the determination of detailed methods necessary to satisfy assumptions required by the estimating procedure. Further development of methods for releasing fish, improvement of recovery gear, and location of proper fish sites to obtain a sufficiently large and representative sample were included. In addition, the experiment was conducted in such a manner that preliminary mortality estimates were obtained during the first year. In 1956

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mortality rates determined in the previous study were confirmed and the results of both years of work were considered adequate for fingerling chinook salmon (fish in the first year). Because the most important runs migrating over McNary Dam, however, pass downstream as fish between 1 and 2 years old (spring chinook, sockeye, and steelhead), an evaluation of mortalities to young migrants is important. Since too few yearling fish would have been required for experimentation at McNary Dam, it was necessary to find a structure similar to McNary Dam but located on a smaller river where larger recovery rates would greatly reduce the total number of fish needed for precise estimation of mortality. Big Cliff Dam on the Santiam River, 35 miles east of Salem, Oregon, satisfied the requirements.

PHYSICAL FEATURES OF THE DAMS

McNary Dam is a low head, river-run hydroelectric installation. The total water capacity of its 14 generating units is approximately 150,000 cubic feet per second, and any water in excess of this amount is discharged over the spillway. The head on the turbines, which are Kaplan wheels, varies between 85 and 90 feet. Each wheel has a diameter of 145 inches and rotates 85.7 revolutions per minute with a resultant velocity at the outer tip of the wheel of 105 feet per second. The spillway gates release excess water over the ogee section and onto energy dissipators which slow the velocity of the water to prevent erosion at the toe of the dam (Figure 1). The physical features of Big Cliff Dam which are related to fish mortalities are very similar to those found at McNary Dam. The turbine is a Kaplan wheel operating under approximately 90 feet of head. Its runner has a diameter of 145 inches and velocity at the tip of the wheel of 103 feet per second. The spillway is a gate-controlled concrete ogee, as at McNary Dam.

Injuries that occur to downstream migrant salmon passing through the turbine of a dam are thought to take place somewhere between the entrance of the penstock and the exit of the draft tube. The water enters a conduit which carries it to the scroll case. It then passes through wicket gates which disseminate the water equally to the variable pitch Kaplan runner, which in turn rotates the generator. The wicket gate opening and the inclination of the runner regulate the amount of water

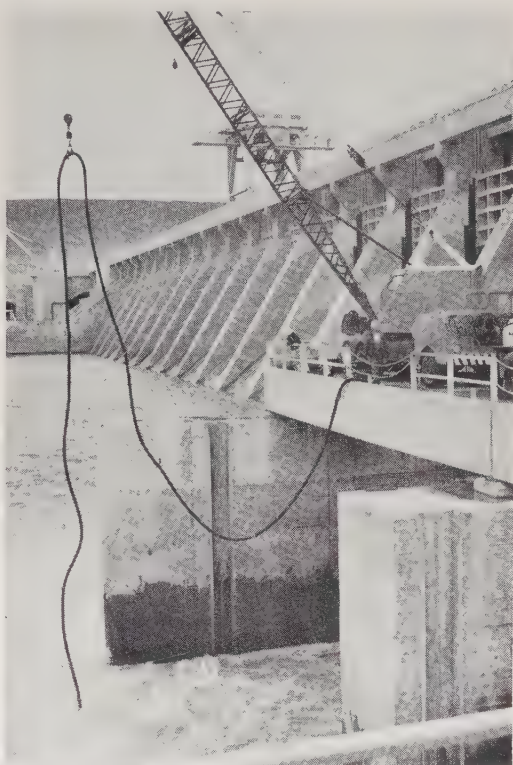


FIGURE 1.—Spillway section of McNary Dam. The hose for release of control fish is being lowered into position in the discharge water of the spillway being tested.

used. After the water has passed the runner, it is discharged into the draft tube and thence to the tailrace. Fish mortalities probably occur somewhere between the scroll case and the draft tube. Although direct evidence is not available, cavitation or local vacuum pockets and physical contact against the wicket gates or the rotating runner probably cause most of the turbine mortalities. It has been assumed for many years that the sudden change in pressure to which fish are subjected while passing through a turbine also causes mortalities. Recent experiments³ subjecting salmon fingerlings to a sudden release from various pressures showed no mortalities at a head of 90 feet with the release of pressure occurring in approximately 5 milliseconds. Since the release of pressure was considerably faster under the experimental conditions than would occur in a Kaplan turbine under similar head,

³ Schoeneman, D., and A. Regenthal. (1957) Flume studies on mortalities to fingerling salmon. Unpublished data, Washington Department of Fisheries.

it is concluded that this factor was not a cause of mortalities at McNary Dam.

Another possible cause of mortality is the spilling process which generally takes place at Columbia River dams during the spring months when most fingerling salmon are migrating. When a spillway gate is raised, water from the forebay spurts under the gate and drops onto the concrete ogee section which carries it to the base of the dam where the tremendous force of the water is spent against the concrete energy dissipators. The cavitation which occurs at pitted areas in the concrete ogee section and the abrasive action of the rough concrete can cause injuries and possible mortalities. Tests on the effects of baffles⁴ eliminate the probability of any significant mortality due to fish striking the energy dissipators. If large quantities of water are being discharged, a back-roll may be created between the energy dissipators and the base of the spillway, with the possibility that fish caught in this back-roll could not escape and would be killed. Areas of danger mentioned above apply to almost every type of hydroelectric structure. The degree of severity, however, may be influenced by height and design of the structure, and the species and age of fish passing through it.

EXPERIMENTAL PROCEDURE

In estimating mortalities on downstream migrant salmon several techniques may be used. The most direct procedure is to introduce live fish into the spillway and penstock of a dam, recover a sample at the outlets of these exits, and observe the live and killed fish in the sample. Such a procedure requires that observed mortalities be caused by the dam and not by the recovery gear. The high velocities present in the recovery area, however, make it difficult to avoid fishing mortalities. In addition, this technique requires that the recovery rates for killed fish and for live fish be the same. Data from a study at Baker Dam (Hamilton and Andrews, 1954) indicate that this assumption was not justified for the recovery gear used. This difficulty was avoided at Baker Dam by releasing marked dead fish with the live plants to determine the recovery rate of killed fish. From these data the mortality rate was determined. This technique assumes that the recovery rates for killed fish and marked dead fish are the same.

Another method was used at Bonnet Dam⁵ in which a group of marked fingerlings was released above the dam, an equal number of fish, differently marked, was released below the dam, and the ratio of the returning adults was studied to determine the mortality due to the dam. With such a procedure a sample of returning adults is often too small to give conclusive results, and a number of years are required to accumulate sufficient data to estimate mortalities. The results of earlier work by Lundbeck (1927) and Caldwell (1935, 1945) were for the most part of a qualitative nature, and attempts to determine mortality rates were inconclusive.

In the work conducted on the Elwha River (Schoeneman and Junge, 1954) studies were designed to determine whether or not a valid and precise estimating procedure could be developed. The technique adopted was similar to the method used by Holmes, but differed in that mortalities due to the individual exits (turbines and spillways) were evaluated separately, and also in that a sample of the juveniles was recovered below the dam instead of waiting for the returning adults. Such a procedure permits an almost immediate assessment of results, so that the experimental techniques may be easily duplicated or modified. Further, a much larger sample is available which permits more sensitive statistical tests and narrower confidence intervals on the mortality rates. In order to apply this method to conditions existing on the Columbia River, experimental details were modified and the extent of the assumptions was extended as indicated below.

The procedure used for determining confidence intervals on the mortality rates is given in detail in the 1954 publication. Junge and Bayliff (1955) extended the application of this confidence interval. Tests on the ratio of Poisson means given by Chapman (1954) serves as a basis for this development.

Assumptions

The validity of the procedure used here is dependent upon a number of assumptions.

- 1) If results from more than one release are combined for the computations, the mortality rate must be the same for each release.
- 2) Recovery gear is not selective.

⁴ See footnote 3.

⁵ Holmes, H. (1952) Manuscript, U. S. Fish and Wildlife Service. Method proposed by Rich (1951).

with respect to the paired marks used or with respect to the condition of the fish.

If the control and experimental fish do not come down in the same ratio, i.e., if the rate of migration is not the same for the two groups, then (a) the nets must fish at a constant rate within each recovery period, and (b) the difference between rate of migration (to the point of recovery) for experimental and control fish must not be great enough to add significantly more natural mortalities to a delayed group.

Either the mortalities being studied are selective with respect to size (and other characteristics) or the recovery gear is not selective with respect to size (and the same characteristics).

The experiment was designed to satisfy the assumptions if possible, and techniques were devised to test whether or not the assumptions were satisfied.

Test of assumptions

In order to test these assumptions it is necessary that the experimental procedure be repeated with identifiable releases. In addition, the recovery effort must be divided into two locations on the river below the dam and. When recovery units are fished in a designated area, they are referred to as a station. Two batteries when fished on opposite banks of a river in the same locality are referred to as a station.

In testing the various assumptions, the most important variable to be examined is the ratio of experimental recoveries to the control recoveries. This ratio is referred to as the "recovery ratio." With the above arrangement the following tests of assumptions can be made.

Test 1, Consistency of recovery ratio by experiment.—Assumption number 1 may be tested directly by applying a standard chi-square test to the number of control and experimental recoveries for the duplicate experiments. Further, when no significant variation between experiments is indicated, an exact verification of assumption number 1 is obtained since a variable fishing rate in the experiments would give variable recovery ratios unless the control and experimental fish migrate in the same ratio (in the case constancy of fishing rate is unimportant), or the variation in the recovery ratio is periodically uniform with respect to the two experiments (which is extremely unlikely).

Test 2, Consistency of recovery ratio by battery.—Inability to satisfy assumption number 2 would generally result from incomplete mixing of the experimental and control fish, particularly if the design of the recovery gear is adequate. This may be measured by comparing the recovery ratios of batteries on the right shore to batteries on the left shore of the river. This comparison may also be made by a standard chi-square test. If no significant variation is found, this gives a limited test of assumption number 2 and permits the following more conclusive test to be made.

Test 3, Consistency of recovery ratio by station.—After combining the data for the two batteries at each station, the recovery ratio between stations may be tested. If there is no significant variation, this offers strong evidence that assumptions 2, 3-a, and 3-b are satisfied, since it would be very unlikely that the recovery ratios at different stations would be the same if any of these assumptions were not satisfied. Further, if the stations are far enough apart, it would rule out any effect due to latent mortalities which could occur several days after the fish had been released.

Test 4, Length-frequency comparisons.—Any size selectivity in the mortality being studied can be measured by comparing the length frequencies of the recovered experimental group with the recovered control group. Similarly, any selectivity in the recovery gear can be measured by comparing the length frequencies of the control group before release and after recapture. This may be done by grouping the data into class intervals of sufficient width for the application of a chi-square test. If either of these tests shows no selectivity (both not required), assumption number 4 is satisfied with respect to size.

An over-all test of assumptions 1, 2, and 3 can be made by applying a single test of the hypothesis that the recovery ratio is the same for every battery of every experiment. The satisfaction of all of the above tests will give strong indication that the sample obtained by the recovery gear is adequately representative of the survivors passing down the river and, therefore, that the mortality estimate is valid.

RELEASE OF MARKED FISH

Marking procedure

In the Elwha study (Schoeneman and Junge, 1954) there was some indication that

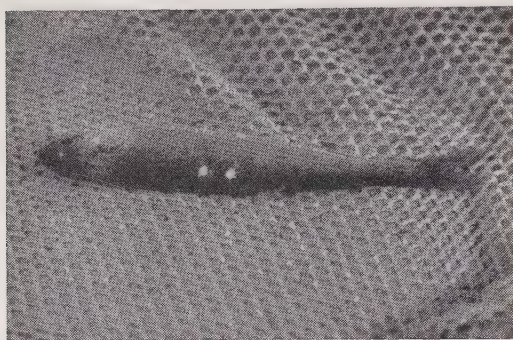


FIGURE 2.—Typical tattoo marks on chinook fingerling.

the ruddering capacity of the fish may have been affected when certain fins were removed. In addition, direct or indirect mortalities due to fin-clipping may bias a mortality study. In order to avoid such effects a more suitable method of marking fish was designed for the McNary Dam project. For this purpose an apparatus was developed which could tattoo large numbers of fish efficiently and with negligible effects. The device used is described by Dunstan and Bostick (1956). For the present study, a sufficient number of distinct marks was obtained by the use of single or double marks of various colors on the left or right side of the fish immediately below the dorsal fin (Figure 2). For the first year's study, 1,230,800 fall chinook fingerlings were tattooed with 12 machines in a period of 1 month. These fish were held before release for an average period of 2 days, during which time less than one-half of 1 percent of all the fish marked died.

In an experiment of this type it is extremely important that the distribution of the fish used in the control and experimental groups be almost identical. Variation in size distribution, percentage from various rearing ponds, and in distribution of holding time before and after marking should be minimized. In order to accomplish this objective, fish were distributed to the markers of the experimental and control groups from a common source, and neither group was permitted to exceed the other group by a significant number of fish. This number was determined from the total number of fish in a release so that selectivity was limited to a fraction of 1 percent.

Planting procedure

Planting fish at the dams twice each week coordinated marking and release operations

quite well. In order to terminate all experiments before normal high water conditions the main period of experimentation at McNary Dam was confined to the month of May while at Big Cliff Dam the safe period was from the middle of March through April. Releases for which adequate recoveries were made are listed in Tables 1 and 2. Omissions were made only when estimation was clearly impossible, so that no bias was introduced by elimination. For example, in 1956 high water in the latter part of March made most direct recovery gear inoperative. As a result, the magnitude and inconstancy of the recovery rate invalidated the estimating procedure for releases made after March 21.

Marked fish were transported from the hatchery to the dam in two planting trucks which permitted the simultaneous releases of the control and experimental groups. Planting hoses, 3 inches in diameter, were used for releases. They were steel-reinforced to prevent collapse under pressure and rubber-lined to eliminate injuries to the fish from abrasion. To test this method of planting, fish were released from a planting truck in the same manner as in the general experiment, except that the head differential under the test conditions was considerably greater. Since no mortalities were observed, it was concluded that this method was adequate.

For the spillway studies, the gate openings were set to simulate conditions which would normally exist during the late spring migration when downstream migration is greatest. At McNary Dam the gate of the spillway which was tested was opened 5 feet and the adjacent gates 4 feet to act as a confining influence. In the 1955 McNary Dam study, the spillway control fish were released below the energy dissipators at the edge of the main flow of the three spillways. In 1956, however, in order to improve initial mixing of the control fish with the experimental fish, the control planting hose was placed directly in the charge of the test spillway just below the energy dissipators (Figure 1). At Big Cliff Dam, a 2-foot gate opening was tested in place of the 5-foot gate opening, with no additional spillage. If McNary Dam spillway conditions had been repeated, the resulting flow would have been a violation of federal regulations. The control groups for both the spillway and turbine studies at Big Cliff Dam were released directly into the river a short distance from the dam since the narrowness of the river canyon downstream eliminated the problem.

1.—Schedule of chinook releases at McNary Dam, 1955–56

Experiment number	Date	Number	Point of release	Group
1	March 4, 8, 11, 1955	30,000 ¹	Turbine ²	Experimental
		30,000	Turbine	Control
		30,000	Spillway ³	Experimental
		30,000	Spillway	Control
2	March 15, 18, 22, 1955	30,000	Turbine	Experimental
		30,000	Turbine	Control
1	March 9, 13, 1956	30,000	Turbine	Experimental
		30,000	Turbine	Control
		30,000	Spillway	Experimental
		30,000	Spillway	Control
2	March 16, 20, 1956	30,000	Turbine	Experimental
		30,000	Turbine	Control
		30,000	Spillway	Experimental
		30,000	Spillway	Control

900 were released on each date so that a total of 90,000 of each mark was released in 1955 and a total of 60,000 of each mark in 1956.

² In 1955 a turbine setting of 0.80 and in 1956 0.75 was used; values refer to the percentage opening of the wicket controlling the water passing through the turbine; 0.80 is normal overload.

³ For spillway releases, gates were raised to permit a 5-foot layer of water to pass over the upper end of the spillway.

Equal mixing of experimental and control fish. For the experimental releases at both McNary and Big Cliff the lower 1 foot of hose was bent in the shape of a circle so that the water movement in order to prevent injuries that might occur should the fish emerge at right angles to the water movement instead of parallel to it.

The planting procedure for the turbine experiments was essentially the same as that for the spillway. The planting hose for the experimental fish was placed in the top of the penstock where the water velocities approximated 5 feet per second, while the control hose was submerged near the center of the discharge of the turbine at McNary Dam.

RECOVERIES

Recovery gear

The recovery gear developed to recover suitable numbers of tattooed fish and to withstand the severe pressures was similar to an inclined plane trap with water flowing into the inclined plane rather than away from it (Figure 3). The upstream opening measured 6 feet by 6 feet and the longitudinal frame was 16 feet from the front to the live box, resulting in a rise of 1.5 feet for each 4 feet of length. The side panels tapered from 6 feet at the front to 8 inches at the live box. Since the top was not covered the framework had

2.—Schedule of yearling and fingerling chinook releases at Big Cliff Dam, 1957

Experiment number	Date	Number	Point of release	Group
Spring chinook yearling releases				
1	March 22, 26	5,000 ¹	Turbine ²	Experimental
		5,000	Turbine	Control
		5,000	Spillway ³	Experimental
		5,000	Spillway	Control
2	March 29, April 2	5,000	Turbine	Experimental
		5,000	Turbine	Control
		5,000	Spillway	Experimental
		5,000	Spillway	Control
1	April 5, 9	5,000	Turbine ²	Experimental
		5,000	Turbine	Control
		5,000	Spillway	Experimental
		5,000	Spillway	Control
Fall chinook fingerling releases				
2	April 12, 16	5,000	Turbine	Experimental
		5,000	Turbine	Control
2	April 12	5,000	Spillway	Experimental
		5,000	Spillway	Control
1	April 17	5,000	Turbine ²	Experimental
		5,000	Turbine	Control
2	April 19	5,700	Turbine ²	Experimental
		5,700	Turbine	Control

¹ Number released on each date listed.

² Turbine setting for turbine was 0.80 except for releases of April 17 and 19, when setting was 0.40.

³ Spillway gate raised 2 feet for spillway releases.

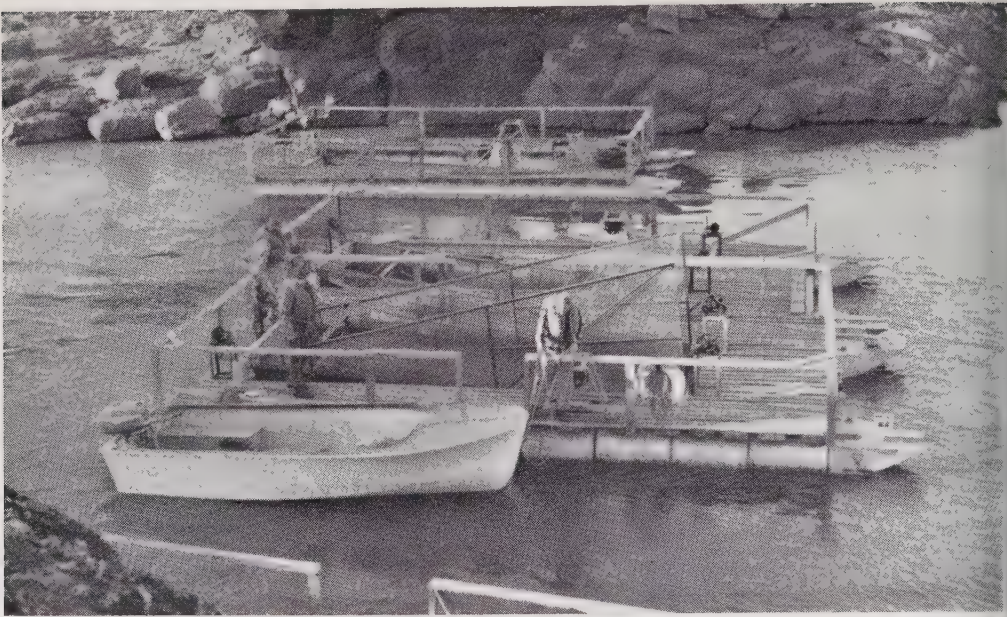


FIGURE 3.—A battery of gear fishing on the Columbia River near The Dalles, Oregon, in 1956.

an appearance similar to a sugar scoop. The frames were covered with $\frac{1}{4}$ -inch-mesh galvanized hardware cloth. The net and live box were supported by cables which were connected to winches at the four corners. This arrangement permitted various net and live-box positions, as well as complete lifting from the water.

The efficiency of the recovery gear is dependent upon a number of factors. Most important of these is the velocity of the water approaching the net. It had been determined in the Elwha studies (Schoeneman and Junge, 1954) that a minimum velocity of 3 feet per second is necessary to recover and retain downstream migrants nonselectively. Optimum water velocities range from 3 to 6 feet per second. Velocities higher than 6 feet per second, while still adequate to catch fish, place undue strain on the recovery gear, especially when there is a large amount of debris. In large rivers such as the Columbia the recovery gear should be placed as close to the shore as the draft of the gear will allow. Mains⁶ found that downstream migrant salm-

on fingerlings favor the shore areas of rivers. Areas where the water is forced from shore around a point of land or a bend where the water is forced into a pool were usually found to have the greatest density.

Fishing procedure

Various fishing stations were chosen on the basis of the physical criteria mentioned above, and the distances between stations were selected according to the characteristics of the river system. On the Columbia River the distance between stations was from 20 to 30 miles, while the Santiam River stations were separated by 1 mile.

In the McNary Dam studies a total of 12 scoop nets in 1955 and 14 in 1956 were fished in pairs at the first two recovery stations. At least one pair was fished on the Oregon shore and one on the Washington shore at each station, with additional pairs in the most productive areas. Rafts were paired so that the capacitance of one raft would not limit the battery void of data. At Bonneville Dam the third station, inclined plane traps already stalled in the dam were located on the Oregon shore as well as on the Washington shore at Bradford Island and on the Washington shore.

Since the narrowness of the Santiam River precluded the use of opposite shore batteries, a single battery of four rafts was fished

⁶ Mains, E. M., and Smith, J. M. (1955) Determination of the normal stream distribution, size, time and current preferences of downstream migrating salmon and steelhead trout in the Columbia and Snake Rivers. State of Washington, Department of Fisheries. Report to U. S. Army Corps of Engineers. Unpublished.

of two stations at distances of 5 and 6 miles below Big Cliff Dam.

Efficiency of recovery gear

From velocity data taken in 1955 it was possible to calculate the percentage of the Columbia River strained by the recovery gear. Relative efficiency of the gear was measured by comparing the percentage of the control releases recovered to the percentage of fish strained. At the first station approximately 20 miles below McNary Dam, 0.65 percent of the water was strained and 0.61 percent of the control releases were recaptured. At the second station 68 miles below the dam, 2.1 percent of the water took 0.26 percent of the fish. At the third station 150 miles below McNary Dam, 1.7 percent of the water took 0.12 percent of the fish.

The increasing difference between the percentage of water strained and fish caught may indicate reduced availability as the fish migrate downstream. This decrease could be caused by natural mortality or by migrational delay. Natural mortality is a more probable cause since the delay in migration, as measured by the percentage recaptured 3 days or more after the last release of each group, averaged only 4.3 percent for recoveries at the first station. Further indication is given by recovery rates at Bonneville Dam of successive control releases of growing fish. For the first and, therefore, smallest fish planted in early March there was a recovery rate of over 100,000 released. Larger fish released in mid-March had a recovery rate of 114 per 100,000 released, and from the largest fish (approximately 10 millimeters greater in average length than the initial group), which were the last to be planted, 175 per 100,000 were recovered. An examination of these conditions gives no indication that this increased recovery rate could be due to increased efficiency of the traps. Such a reduction in availability of smaller fish at the first station coupled with the reduced availability of fish in general as they progress far downstream the river could indicate a high natural mortality.

In 1957 on the Santiam River below Big Cliff Dam, the nets fished with a high degree of efficiency and at a remarkably constant rate. Out of the 171,400 fish released 60,641 were recovered by the eight scoop nets. Recovery rates as determined from the control releases were 39.9 and 40.3 percent respectively for the yearling and fingerling releases in the

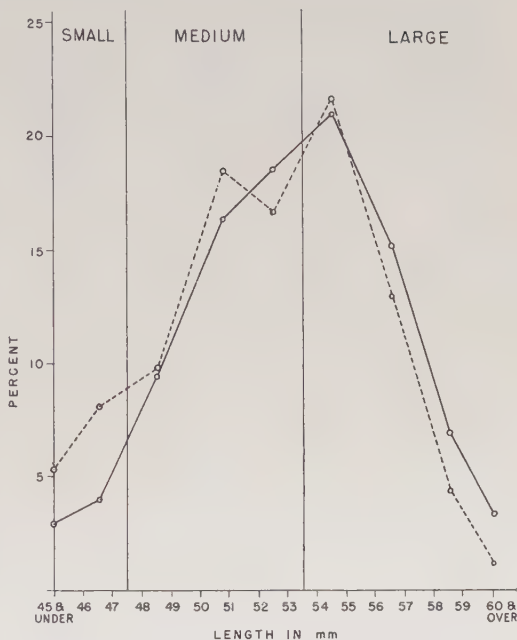


FIGURE 4.—Length-frequency comparison of chinook fingerlings released at McNary Dam and recovered at station 1, 1955. Dotted line represents measurements before release ($N = 705$) and solid line represents measurements after recovery ($N = 744$).

0.80 rating turbine studies, and 38 and 37 percent for the yearling and fingerling releases in the spillway study, indicating a very constant recovery rate with respect to both time and size of fish. Since a constant recovery rate for a given release is adequate for many of the assumptions involved in the experimental technique used, such observed consistency throughout the whole time period gives added confidence in the validity of the mortality estimates.

Length-frequency measurements were taken for some releases before planting and again after recapture. The 1955 Columbia River results indicated that a significantly smaller percentage of chinook fingerlings under 47.5 millimeters were present among the recoveries than among the released group (Figure 4). Since the fish measured after recapture included both the experimental and control groups and no significant difference in length was found between these groups, the effect illustrated in Figure 4 is probably due either to selectivity of the mesh size of the screen or to natural mortality. Regardless of the causes of these variations, length-frequency assumptions for estimating mortalities are adequately

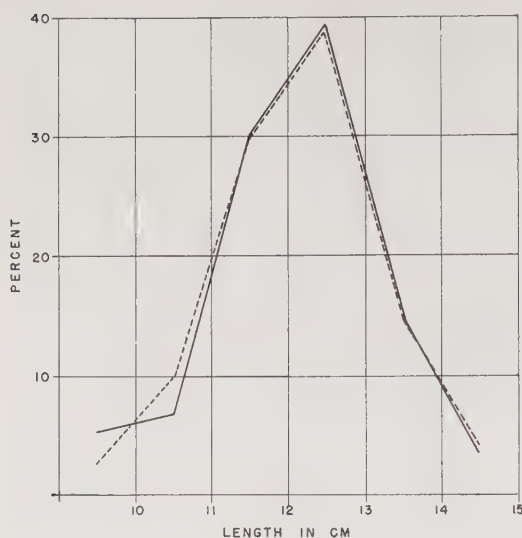


FIGURE 5.—Length-frequency comparison of yearling chinook released at Big Cliff Dam and recovered at station 1, 1957. Solid line represents measurements before release ($N = 200$) and dotted line represents measurements after recapture ($N = 415$).

satisfied since no significant variation in length frequencies was found between control and experimental recoveries.

In view of the adequacy of length-frequency comparisons at McNary Dam, no fingerlings were measured in the experiments conducted on the Santiam River in 1957. Yearlings were studied, however, to determine whether or not the fishing gear or the dam mortalities were selective with respect to their size. A comparison of fish measured before release and after recovery showed no significant difference ($P > 0.50$), indicating that there is no fishing selectivity with respect to size (Figure 5). In addition, a comparison of turbine experimental recoveries to control recoveries shows that this kill is not selective with respect to size ($P > 0.20$) (Figure 6). An even stronger indication of the absence of size selectivity in the recovery gear is shown by the duplicability of the recovery rates for fingerling and yearling chinook.

RESULTS OF TURBINE STUDIES

During the 3-year study, mortality rates were estimated for three different turbines at two dams on two age groups of chinook salmon. Results (Table 3) show a high consistency for the various phases studied under a normal overload operation (75 and 80 percent wicket-gate opening). No significant differ-

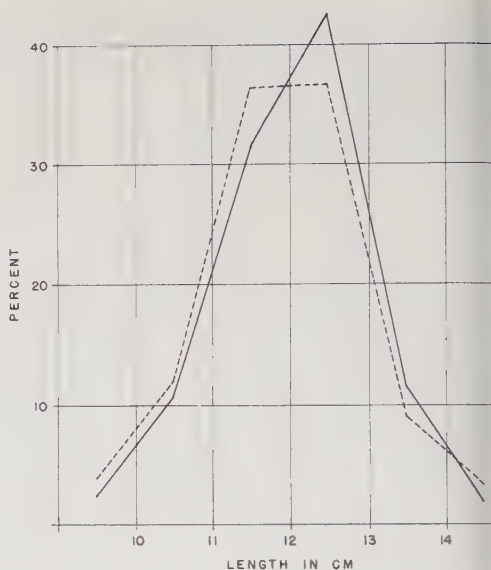


FIGURE 6.—Length-frequency comparison of experimental and control recoveries of yearling chinook used in turbine study, Big Cliff Dam, 1957. Solid line represents control recoveries ($N = 381$) and dotted line represents experimental recoveries ($N = 324$).

ence is indicated between the two turbines in the study. The consistency between the data observed at McNary Dam, between Big Cliff Dam and McNary Dam turbines, or between fingerling and yearling chinook, or between zero-group and yearling chinook. This consistency permits the data to be combined, giving an estimated mortality rate of 11 percent with a 95 percent confidence interval of 9 to 13 percent.

Experimentation with a 40 percent wicket-gate opening using fingerling chinook at Big Cliff Dam gave a mortality of 21 percent with a 95 percent confidence interval of 17 to 25 percent. Compared with a normal overload operation, the increased mortality using a 40 percent opening is highly significant, and may be due to the increased cavitation which usually accompanies such a change. This result is in agreement with the observations of Cawood (1935) on a Francis-type turbine. Operation with a 40 percent wicket-gate opening is infrequent, and it is unlikely that such a setting would be used at Columbia River dams during the main portion of the downstream salmon migration.

In addition to the consistency shown in Table 3, each of the studies satisfied the tests designed to determine the validity of the various assumptions involved in the estimation procedure. Detailed data by station, show-

FIG. 3.—Summary of results of turbine studies at McNary Dam (1955 and 1956) and at Big Cliff Dam (1957)

Net-gate opening percentage)	Dam	Chinook studied	Experimental recoveries	Control recoveries	Estimated survival (percentage)	Confidence interval
80	McNary, 1955	Fingerling	1,425	1,639	87	—
75	McNary, 1956	Fingerling	960	1,039	92	—
75, 80	McNary, combined	Fingerling	2,385	2,678	89	—
80	Big Cliff, 1957	Fingerling	7,056	8,056	88	—
80	Big Cliff, 1957	Yearling	7,248	7,975	91	—
80	Big Cliff, combined	Fingerling and yearling	14,304	16,031	89	—
75, 80	Both dams, combined	Fingerling and yearling	16,689	18,709	89	87-91 percent
40	Big Cliff, 1957	Fingerling	3,554	4,492	79	76-83 percent

erty, and experiment number for the 1955 and 1956 studies at McNary Dam are shown in Table 4. Data by station and experiment number for each of the two age groups tested at Big Cliff Dam in 1957 are included in Table 5. Except for length-frequency studies which have already been discussed, all the necessary chi-square tests can be made from these data.

An example of the application of the over-all chi-square test for the consistency of ratios from duplicate experiments at all stations is given in Table 6. The eight categories compared are the control and experimental recoveries for the four batteries involved in the two experiments at McNary Dam in 1955. Here, a chi-square value of 6.934 with 7 degrees of freedom corresponds to a probability level greater than 0.45. Most of the chi-square tests compare only two categories. For example,

Table 7 compares the recovery ratio for the raft recoveries at all batteries with the recovery ratio of the Bonneville Dam recoveries in the 1955 study. A chi-square value of 1.579 with 1 degree of freedom here corresponds to a probability level greater than 0.25. Since Bonneville Dam is approximately 150 miles below McNary Dam, the results of this test indicate that no significant differential latent mortality took place between the raft stations and Bonneville Dam. In this respect it may be pointed out that the Elwha study (Schoeneman and Junge, 1954) found no significant differential latent mortalities occurred below a station 1 mile below the dam. This observation is important, since the lower station on the Santiam River was less than 6 miles below Big Cliff Dam.

The results of the various chi-square tests are given in Table 8 for the McNary Dam

TABLE 4.—Fish recoveries from turbine experiments at McNary Dam, 1955-56

		Battery									
Station number	Experiment number	Washington		Bradford Island		Oregon		Combined			
		Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control		
55 (Bonneville Dam)	1	1	315	374	—	—	120	149	435	523	
		2	275	301	—	—	124	127	399	428	
	2	Total	590	675	—	—	244	276	834	951	
		1	119	119	—	—	110	134	229	253	
		2	56	65	—	—	139	199	195	264	
		Total	175	184			249	333	424	517	
	3	Total	50	42	74	87	43	42	167	171	
	All stations		Total						1,425	1,639	
	56 (Bonneville Dam)	1	1	160	191	—	—	90	69	250	260
			2	194	220	—	—	134	160	328	380
2		Total	354	411	—	—	224	229	578	640	
		1	47	39	—	—	152	160	199	199	
		2	38	27	—	—	73	87	111	114	
		Total	85	66	—	—	225	247	310	313	
3		Total	57	67	3	4	12	15	72	86	
All stations		Total						960	1,039		
1956 Combined								2,385	2,678		

TABLE 5.—Fish recoveries from turbine experiments at Big Cliff Dam, 1957

Wicket gate opening (percentage)	Station number	Experi- ment number	Spring chinook (yearlings)		Fall chinook (fingerlings)		Combined	
			Experi- mental	Control	Experi- mental	Control	Experi- mental	Control
80	1	1	2,373	2,703	2,474	2,867	—	—
		2	2,530	2,764	2,562	2,910	—	—
		Total	4,903	5,467	5,036	5,777	9,939	11,244
	2	1	1,214	1,363	986	1,088	—	—
		2	1,131	1,145	1,034	1,191	—	—
		Total	2,345	2,508	2,020	2,279	4,365	4,787
	All stations	Total	7,248	7,975	7,056	8,056	14,304	16,031
40	1	1	—	—	1,216	1,488	—	—
		2	—	—	1,340	1,758	—	—
		Total	—	—	2,556	3,246	—	—
	2	1	—	—	482	657	—	—
		2	—	—	516	589	—	—
		Total	—	—	998	1,246	—	—
	All stations	Total	—	—	3,554	4,492	—	—

studies and Table 9 for the Big Cliff Dam studies. In general, a probability level less than 0.05 would be considered indicative of significant variation. The range from 0.07 to 0.95 for these values is consistent with a process involving random sampling from populations with the same recovery ratio for the catches at each battery for each of eight independent experiments. The very low probability level for the 80 percent *vs.* 40 percent wicket-gate opening test shows that the increased kill with the 40 percent opening is very significant.

The results of the present study may be applicable to turbines at other river-run dams on the Columbia River such as Bonneville and The Dalles where similar Kaplan wheels are used with similar heads and operating conditions. Quite different results, however, may occur for other types of turbines under varying heads. In the Elwha study an estimated mortality of 30 percent was found at Glines Dam with a Francis wheel under 200 feet of head, although no significant kill was ob-

served at Elwha Dam through a Francis wheel with 100 feet of head. At Baker Dam (Hartson and Andrews, 1954) a mortality of about 30 percent was estimated for a Francis wheel under 250 feet of head.

RESULTS OF SPILLWAY STUDIES

The spillway studies at McNary Dam and Big Cliff Dam are summarized in Table 6. Since no significant variation is indicated between the two dams and two age groups studied, results have been combined to obtain an estimated mortality of 2 percent with a 95 percent confidence interval of 0 to 4 percent. A one-sided test indicates that the kill is significant ($P < 0.05$).

In obtaining the above estimates, certain variations in the McNary Dam studies should be noted. Only a single experiment in 1955 was used in the calculations, and for it as well as for the two experiments in 1956, the recovery ratio at select areas differed very significantly from the recovery ratio for the other areas. Because of the eventual use of the

TABLE 6.—Over-all chi-square test for consistency of ratio for duplicate experiments at all stations [Turbine studies—McNary Dam, 1955]

Station	Battery	Experi- ment number	Control recovery	Experi- mental recovery	Total	Expected value of control	Difference (control and expected value)
1	Oregon	1	149	120	269	144.86	4.14
		2	127	124	251	135.17	-8.17
	Washington	1	374	315	689	371.04	2.96
		2	301	275	576	310.19	-9.19
2	Oregon	1	134	110	244	131.40	2.60
		2	199	139	338	182.02	16.98
	Washington	1	119	119	238	128.17	-9.17
		2	65	56	121	65.16	-0.16
Total			1,468	1,258	2,726		

Chi-square = 6.934, $P > 0.45$

TABLE 7.—*Chi-square test for raft recoveries vs. Bonneville recoveries*

[Turbine studies—McNary Dam, 1955]

	Control recoveries	Experimental recoveries	Total	Expected value of control	Difference (control and expected value)
Bonneville	1,468	1,258	2,726	1,458.73	9.27
McNary	170	165	335	179.27	-9.27
Total	1,638	1,423	3,061	—	—

Chi-square = 1.579, $P > 0.25$

Two groups of samples one will be referred to as the "nonrepresentative sample" and the other as the "representative" sample. In 1955, only nonrepresentative sample was taken at the Washington shore station at Bonneville Dam. In 1956, station 2 was located approximately 1 mile below The Dalles Dam which was under construction at that time. The nonrepresentative sample in 1956 was taken at that station by the Washington batteries and a single raft which was against the Oregon shore. The nonrepresentative sample had a very constant recovery ratio for the 2 years and the three areas considered, with an average value for the combined data of 0.60 (Table 11). The representative sample which consisted of all other recoveries also had a very consistent recovery ratio for the several years and the three experiments considered, with an average value of 1.00 (Table 12).

A number of considerations suggest that the nonrepresentative sample is a portion of a small population of fish which separates in areas of slack water. First, the nonrepresentative sample consisted of a total of 1,258 fish compared to a total of 3,788 fish in the representative sample. Furthermore, nonrepresentative recoveries were made in shore areas immediately below slack water which included a high percentage of fish leaving the spillway areas, whereas the representative sample took only a very small percentage of the highly migrant fish. For example, in 1955 only nonrepresentative sample was obtained on the Washington shore of Bonneville Dam during a period when no spilling occurred, so that the main flow of the river followed the Oregon side of Bradford Island. In 1956, when spilling occurred all traps at Bonneville Dam took representative samples indicating that when the groups are mixed the effect of the nonrepresentative sample is negligible. Finally, the recovery ratio for the Big Cliff Dam spillway study was not significantly

TABLE 8.—*Probability level of various chi-square tests for turbine studies (75–80 percent wicket-gate opening), McNary Dam, 1955, 1956*

Year	Test	Probability level
1955	Over-all test	0.45
	Washington vs. Oregon batteries	0.25
	Station 1 vs. station 2	0.60
	Experiment 1 vs. experiment 2	0.95
	Three Bonneville traps	0.40
	Bonneville vs. rafts	0.25
	Length frequency:	
	Control vs. experimental	0.30
	Over-all test	0.10
	Washington vs. Oregon batteries	0.75
1956	Station 1 vs. station 2	0.35
	Experiment 1 vs. experiment 2	0.30
	Bonneville vs. rafts	0.50
	1955 vs. 1956	0.25

different from the recovery ratio for the representative sample at McNary Dam. At Big Cliff Dam the relatively higher mortality of 6 percent on fingerlings is based on a larger sample which was taken under more ideally controlled conditions and may be more representative of the mortality rate for fingerling chinook.

Recoveries for the representative samples at McNary Dam in 1955 and 1956 are shown in Table 12. Table 13 shows recoveries for the spillway studies at Big Cliff Dam. The same chi-square tests as those used for the turbine studies were applied and the probability levels for these tests determined (Tables 14 and 15).

The results at McNary Dam and Big Cliff Dam spillways may be applicable to other river-run dams located on the Columbia River. Different type structures of various heights, however, will alter these results significantly. A 250-foot fall or drop spill at Baker Dam (Hamilton and Andrews, 1954) which strikes against the concrete face of the spillway, for example, had an estimated kill of greater than

TABLE 9.—*Probability level of various chi-square tests for turbine studies with 80 percent and 40 percent wicket-gate openings, Big Cliff Dam, 1957*

Gate	Test	Probability level
80 percent	Over-all test	0.20
	Station 1 vs. station 2	0.20
	Experiment 1 vs. experiment 2:	
	yearling	0.07
	fingerling	0.30
	Yearling vs. fingerling	0.10
	Length frequency: Control vs. experimental (yearlings)	0.20
	McNary (1955–56) vs. Big Cliff (1957)	0.95
	Over-all test	0.10
	Station 1 vs. station 2	0.70
40 percent	Experiment 1 vs. experiment 2	0.95
	80 percent vs. 40 percent, wicket-gate opening	0.00001

TABLE 13.—*Recoveries of fish from spillway studies, Big Cliff Dam, 1957*

Station number	Experiment number	Yearling chinook		Fingerling chinook		Combined	
		Experimental	Control	Experimental	Control	Experimental	Control
	1	2,274	2,205	1,372	1,421	3,646	3,626
	2	2,731	2,774	1,095	1,204	3,826	3,978
	Total	5,005	4,979	2,467	2,625	7,472	7,604
	1	1,332	1,336	545	573	1,877	1,909
	2	1,184	1,260	459	495	1,643	1,755
	Total	2,516	2,596	1,004	1,068	3,520	3,664
Combined	1	3,606	3,541	1,917	1,994	5,523	5,535
	2	3,915	4,034	1,554	1,699	5,469	5,733
	Total	7,521	7,575	3,471	3,693	10,992	11,268

a mortality rates apply equally well to Salmonidae and to other low head, river-dams on the Columbia River.

With a 2 percent mortality over the spillway and an 11 percent mortality in the turbine, the over-all mortality to natural downstream migrants must be between these two percentages and would depend on the percentage of fish utilizing each of these exits. The over-all mortality depends upon the distribution of the fish in the forebay and the time distribution of migration over the dam. Since these distributions are not well defined at present, only a very rough approximation of the total mortality may be calculated. If it is assumed that somewhat more than half of the fish pass over the spillway, the resulting mortality for the turbine alone would be approximately 6 percent. Fish passing a series of 10 such dams would experience a total mortality of 45 percent. With optimum water control at storage dams, all of the fish would be forced to use the turbine exit with a resulting mortality in a series of 10 dams of almost 70 percent. In view of this serious condition, the necessity of devising a method to divert migrants from the turbine exit of danger is obvious if the Columbia

River stock of salmon is to be maintained at a commercial fishing level.

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TABLE 14.—*Probability level of various chi-square tests for spillway studies, McNary Dam*
["Representative" samples only]

Test	Probability level
Over-all test at all stations	0.98
Washington vs. Oregon batteries	0.75
Station 1 vs. station 2	0.85
Release 1 vs. release 2 at station 1	0.75
Bonneville vs. rafts	0.80
Length frequency:	
Control vs. experimental	0.60
Over-all test at all stations	0.30
Station 1 vs. station 2	0.55
Experiment 1 vs. experiment 2	0.15
Bonneville vs. rafts	0.97
1955 vs. 1956	0.60

TABLE 15.—*Probability level of various chi-square tests for spillway studies, Big Cliff Dam, 1957*

Test	Probability level
Over-all test at all stations	0.30
Station 1 vs. station 2	0.40
Experiment 1 vs. experiment 2:	
yearling	0.15
fingerling	0.30
Yearling vs. fingerling	0.06
McNary (1955-1956) vs. Big Cliff (1957)	0.50

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Diurnal Periodicity in the Activity of *Petromyzon marinus* and the Effects of Chemical Stimulation

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ABSTRACT

Both the transforming ammocoete and parasitic *Petromyzon marinus* display an endogenous cyclic activity rhythm. The rhythm is gradually lost in constant conditions of dim light but is re-established by exposing the animal to one or two artificial diurnal light cycles. The period of the endogenous cycle in one larva was 22 hours 58 minutes. Rhythm in the parasite can also be re-established by exposing the animal during a single short period to chemical sensory stimulation produced by the scent of fish. Diurnal rhythm so established was maintained during a period of 5 days at the end of which the observations ceased. Sensory stimulation can function as a "setting" mechanism of the physiological clock. In this instance the setting mechanism is not related to the metabolism of the animal but must have its seat in the central nervous system.

INTRODUCTION

In 1955 the senior author began a series of observations on the mechanisms by which *Petromyzon marinus* is able to localize its prey. During the course of preliminary work it became evident that the initial stimulus leading to activity and final location of the prey is of chemical nature, and that the perception of such chemical stimulation is through the olfactory organ. Part of subsequent studies was directed towards the identification of the chemical nature of the substances which are effective as stimuli (Kleerekoper and Mogen, 1959). As the work progressed, however, at an early stage of the experiments there were indications that this species displays diurnal rhythmic activity and that periodicity of this activity might be used to ascertain experimentally whether or not specific chemical substances can act as stimuli leading to "search" for prey. Since diurnal rhythmic processes in *P. marinus* have been unknown, the literature contains only one study dealing with rhythmic activity in *Lampetra tshawytscha* (Wikgren, 1953), considerable attention was given to the analysis of this phenomenon as well as to the effect of chemical stimulation from water in which brook trout have been retained. The present paper deals with the initial results of these investigations.

METHODS AND MATERIALS

Specimens of the parasitic stage of *Petromyzon marinus* were obtained from Lake Huron and Lake Ontario. The larval forms were received from the U. S. Fish and Wildlife Service Laboratory, Hammond Bay, Michigan, and were captured in the spawning beds

of rivers in that general region. The larvae were held in a completely dark fish tank in a layer of mud 4 inches deep and provided with running well water until required for experiment. The adults were maintained in running water from the same source.

All experiments were conducted with single specimens of larva or parasitic form in a cylindrical tank 205 centimeters (85 inches) in diameter and 25 centimeters (10 inches) high which was sub-divided in 16 sectors (Figure 1, C). The compartments freely communicate in the center area of the tank where an overflow is provided. Water from an activated carbon filter was supplied to the tank through components made of polyethylene or plexiglass. Each of the entrances to the 16 compartments is provided with a photo-electric detection system consisting of a phototube on one side and a 6-volt flashlight bulb on the other. The light of the bulb is directed onto the cathode of the phototube by means of a collector system which almost completely suppresses stray light and diffusion into other parts of the tank. Phototube and light source are housed in plexiglass containers. The pulses produced by the interception of the light beam by an animal entering a compartment are recorded by an apparatus which provides a continuous record of the number of pulses, their origin by compartment, and the time at which they occur. This apparatus was designed and constructed in this laboratory and is described elsewhere (Kleerekoper and Hoekstra, MS).¹

¹ Kleerekoper, H., and J. P. Hoekstra. (1960) The automatic recording of multiple impulses and of the time of their occurrence on inexpensive Kraftpaper by means of a modified electrical typewriter. Manuscript.

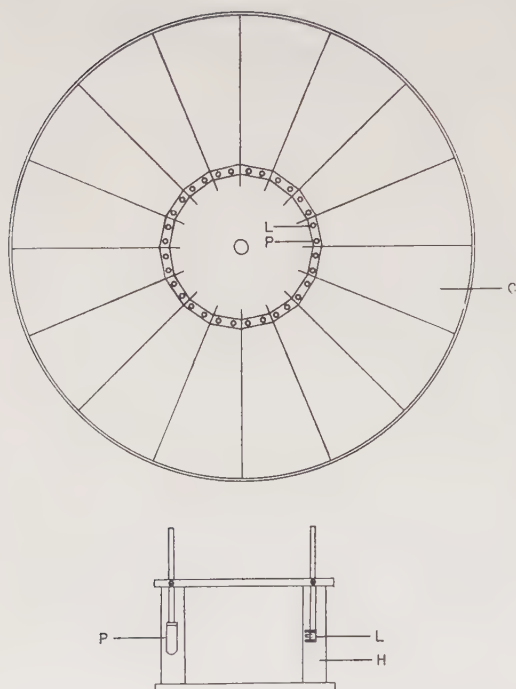


FIGURE 1.—Experimental tank. C, compartment; L, light source with corrugated brass collector; P, phototube; H, watertight containers for photodetector system made of plexiglass.

The experimental tank with its water supply is kept in an aquarium room, which can be totally darkened, and is further protected from stray light by an additional light shield. The recording equipment is kept outside the aquarium room to reduce disturbance of the experiments. Temperature of the water supply is kept between 14° and 16° C. with only slow fluctuations within this range. Since the tank is placed above eye level, direct observation is not possible without the aid of a large mirror placed overhead at an appropriate angle.

RESULTS AND DISCUSSION

The results of the experiments may conveniently be divided into three sections: (1) diurnal rhythm of locomotion under constant conditions of light; (2) the diurnal cycle as affected by alternations of light-dark periods; and (3) the effects of chemical stimulation on the diurnal rhythm of activity of the lamprey.

Diurnal rhythm under constant light

Parasitic lamprey.—The results of the observations during the period of July 29 to August 27, 1958, are presented in Figure 2.

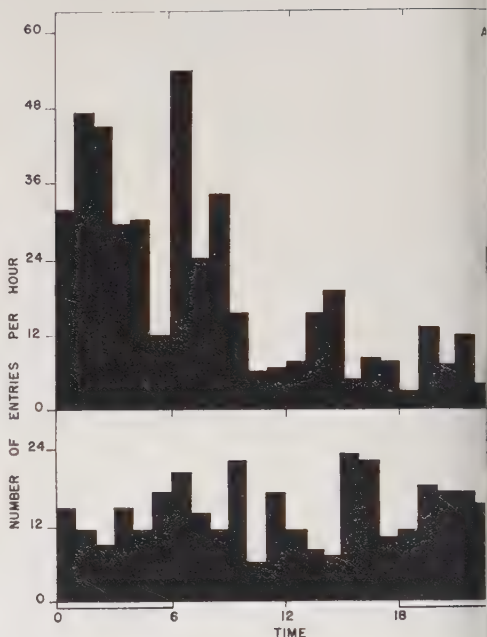


FIGURE 2.—Average hourly activity of *P. marinus* parasite. A, from July 29 to August 27, 1958; B, under constant conditions of dim light from June 24 to July 7, 1959.

The animal used was 30 centimeters long and had been caught when attached to a fish. It had not been fed after entering the laboratory. The first part of this experiment was carried out under conditions of diurnal change of light. Figure 2A is a record of the activity of the animal averaged for the whole period. There is a distinct diurnal rhythm with a main period of activity starting at 2300 E.S.T. with peaks at 200 and 600 E.S.T.

These observations were repeated during the period of June 24 to July 7, 1959, in constant conditions of light. The only light present was very dim stray light of constant intensity from the collectors which direct the light beams onto the phototubes. Water flowed into the tank at a constant rate of 100 liters per hour. Figure 2B suggests an apparent loss of diurnal rhythm under constant conditions of light. Absence of a rhythm could have been brought about by a drift of the animal's physiological clock under constant conditions. If the period of the rhythm is either smaller or larger than 24 hours, cumulative data, averaged over a longer period, must show an apparent loss of rhythm of activity. In this experiment, however, an analysis of the daily data for the period of observations does not show the

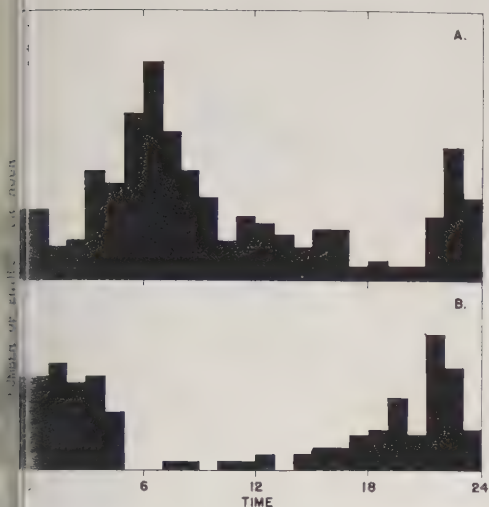


FIGURE 3.—Average hourly activity of *P. marinus* under constant conditions of dim light. A, June 9 to 16; B, June 16 to 23, 1959.

ence of such a drift. It is apparent, therefore, that the parasite under constant conditions of light does not display a diurnal rhythm, a phenomenon observed in a number of other animals and plants (Bünning, 1958; Webb and Brown, 1959).

Transforming larva.—A larva which had been kept for 8 months in constant absolute darkness, except for a short period of dim lighting immediately before the start of the experiment, was used for the observations during the period of June 9–23, 1959. It was 10 centimeters long and in a late stage of development.

The average number of entries per hour into compartments of the tank during 24 hours on June 9 to 16 in continuous dim light of constant intensity indicated periods of high activity from 0100 to 1800 and from 2200 to 0000 E.S.T. with peaks at 0600 and possibly at 2200 (Figure 3A). The most extensive movements occurred from 0300 to 1000 E.S.T. During the period of June 16 to 23 under the same conditions, the periods of intensive activity were found to be from 0000 to 0500 and from 1700 to 0000 with peaks at 0100 and 2100 E.S.T. (Figure 3B). The difference between the two graphs suggests the occurrence of a drift in the period of activity. When the time of occurrence of maximal activity is plotted for successive dates (Figure 4) the period of diurnal cycle is approximately 22:58 hours in this particular animal.

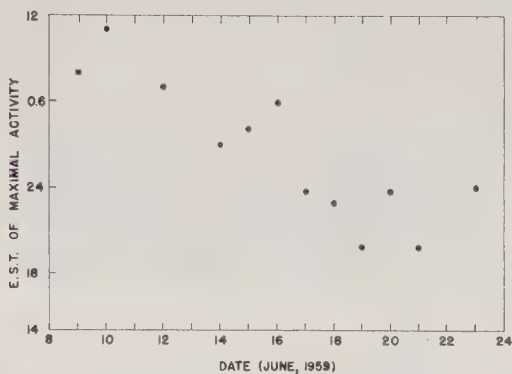


FIGURE 4.—The time of occurrence of maximal activity of *P. marinus* larva in the experiment presented in Figure 3.

Diurnal cycle with alternations of light-dark periods

The effects of light on the diurnal cycle of activity were determined for a transforming larva which had been kept in continuous darkness during a period of 8 months. A continuous record of activity during 15 days indicated the absence of a diurnal cycle (Figure 5A). At the end of the period, the animal was exposed to a sequence of 12 hours of light, 12 hours of darkness, and 12 hours of light. During the dark periods very dim light prevailed at the site of the phototubes. The hourly activity was again recorded after the two diurnal light cycles (Figure 5B). A comparison of this figure with Figure 5A clearly demonstrates the effect of the two light cycles. A well-defined diurnal rhythm was established with maximal activity from 0000 to 1000 hours and a second period of far lesser activity between 1300 and 1800 hours. It was not possible to ascertain how long this diurnal cycle would be maintained under constant conditions of light.

Effects of chemical stimulation on the diurnal rhythm of activity

During 1958 a number of experiments were carried out to determine whether the "scent" of trout in the experimental lamprey tank would affect either the total diurnal activity or the diurnal rhythm of activity. These initial experiments were done by placing brook trout in cages of wire mesh, constructed so as to prevent the visual perception of the trout by the lamprey. These cages were placed in one or more compartments of the tank (Figure 1, C) and were painted with inert paint. To

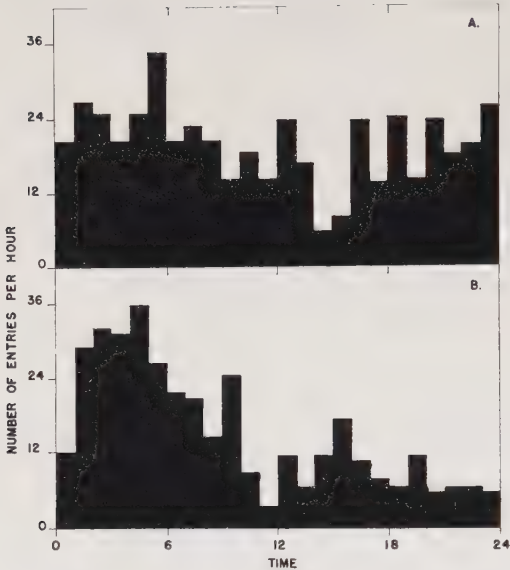


FIGURE 5.—Average hourly activity of *P. marinus* larva. A, in continuous dim light (May 9 to 23, 1959); B, after exposure of the animal to two diurnal cycles of bright light of 12 hours each, with a 12-hour interval (May 26 to June 1, 1959).

eliminate the effect of the cages themselves on the behavior of the lamprey, they were left in the tank during the experiments while the trout were placed inside the cages when required.

In seven separate experiments, the activity of a parasitic lamprey was observed during 24-hour periods in the absence of trout. At the end of each 24-hour period one trout was introduced into the cage. The activity of the lamprey was again recorded during the following 24 hours (Table 1).

There is a marked increase in the total activity of the lamprey, particularly during the 2-hour, but also during the 6-hour periods following the introduction of the trout.

To eliminate any effects from the introduc-

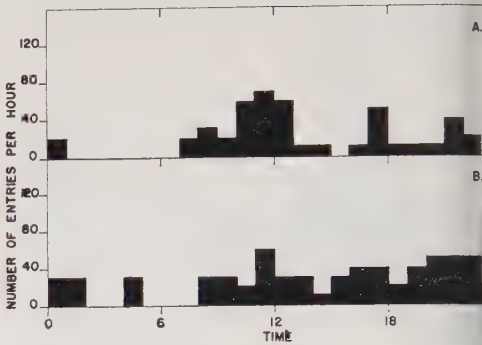


FIGURE 6.—Average hourly activity of *P. marinus* parasite. A, under constant conditions of dim light previous to the introduction of trout scent (July 5 and 9, 1959); B, same (July 10 and 11, 1959).

tion of trout into the cages in the lamprey tank, a different type of experiment was set up to investigate the effect of chemical stimulation on lamprey activity. On July 13, 1959, at 1200 hours, five trout were introduced into an auxiliary tank which was connected so that the water from the supply filter had to pass through it before entering the lamprey tank. After a delay, the lamprey tank would therefore be supplied with water containing the scent of trout. The trout were left in the auxiliary tank from July 13, 1200 hours, to July 15, 1200 hours. It required approximately 4 hours for the water of the auxiliary tank to replace the water in the lamprey tank. During two 24-hour periods prior to the introduction of the trout, the lamprey showed no evidence of a diurnal rhythm (Figure 6).

When "trout water" was introduced into the lamprey tank at 1600 hours, a striking increase in activity occurred (Figure 7A). This increase had no equivalent in any of the previous days during which the activity of the lamprey had been recorded (June 23 to July 13). The response came immediately after the trout water had reached the lamprey tank and

TABLE 1.—The effect of trout scent on the activity of the lamprey. Total activity during 1-hour, 2-hour and 6-hour periods before and after the introduction of the trout

Number of experiment	Number of entries					
	6-hour period		2-hour period		1-hour period	
	Before	After	Before	After	Before	After
8	98	126	98	126	98	40
9	539	97	121	30	—	—
10	287	335	78	193	—	101
11	25	114	—	108	—	52
12	380	541	110	102	—	57
13	58	359	36	134	10	2
14	167	142	—	77	—	29
Total	1,554	1,714	443	770	108	281

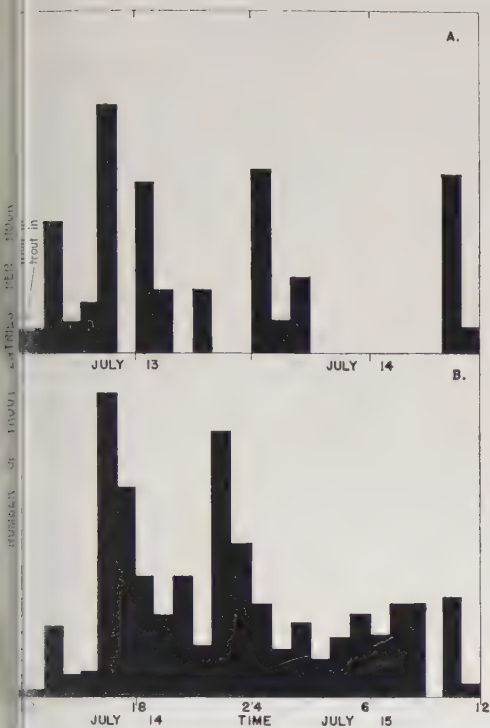


FIGURE 7.—Activity of *P. marinus* parasite with light and light conditions as in Figure 6A. A, effect of introduction of trout scent on the hourly activity during the period of July 13, 1200 hours, to July 14, 1200 hours, 1959; B, activity during the period of July 14, 1200 hours, to July 15, 1200 hours, 1959.

Strongly increased activity was maintained during an additional 24-hour period. On the second day after the introduction of the trout (July 14), the increased activity occurred at about the same time of day that the trout was introduced on the first day (July 13). Of great interest is the repetition, on the second day, without any change in the chemical stimulation, of increased activity at the same time of day at which it had originally been produced (Figure 7B).

To examine this important aspect further, the experiment was repeated on July 15, by introducing 10 liters of water in which 21 lampreys had remained during a period of 42 hours. This water contained approximately 1.5 p.p.m. total nitrogenous compounds, of which 3.0 p.p.m. consisted of amino nitrogen (Brekoper and Mogensen, 1959). The water was introduced at 1430 hours. The introduction was followed by bursts of lamprey activity which lasted from 1600 to 2200 hours and from 200 to 1200 hours with an interruption

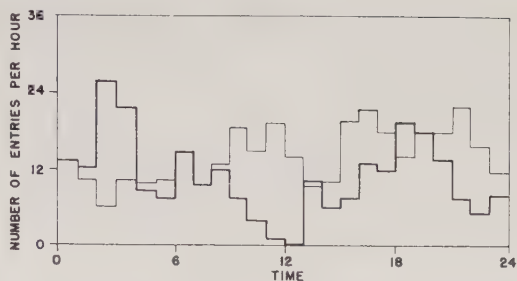


FIGURE 8.—Average hourly activity of *P. marinus* parasite from June 23 to July 13, 1959, in constant conditions of dim light (thin tracing); and from July 15 to 20, 1959, after the introduction of "trout water" on July 15, 1430 hours (heavy tracing).

from 400 to 600 hours. A continuous record of the five following days is presented in Figure 8. The establishment of a very distinct rhythmic activity pattern is evident. No attempt could be made to establish the persistence of this periodicity in the absence of further chemical stimulation.

CONCLUSION

An extensive review of the literature dealing with physiological rhythms and biological "clocks" in both plants and animals was recently published by Bünning (1958), and the phenomena of persistent rhythmicity and the probable mechanisms of its maintenance were surveyed by Webb and Brown (1959). Our results demonstrated that *Petromyzon marinus* is capable of maintaining a cyclic diurnal rhythm in its locomotion. Little or no information on such rhythms in fish is available in the literature, while only a short term observation on another cyclostome has been reported (Wikgren, 1953). Rhythmic activity can be released in both the ammocoete and the parasitic stage of *P. marinus* by exposure to one or two light-dark periods in much the same way as has been described for a number of plants and animals (Bünning, 1958).

That diurnal rhythm can be initiated also by a single sensory stimulation of chemoreceptors was demonstrated by the present study. The literature makes no reference to similar observations on other organisms, and it seems difficult to relate our results to those published by other workers referring to the effect of chemical factors on endogenous rhythms. Most of the observations published to date refer to chemical factors related to the normal or abnormal metabolic processes

in the organism (Bühnemann, 1955a and b; Bünning, 1956, 1957; Renner, 1957, 1958).

Our observations on the effect of trout scent on the diurnal rhythm of activity of the lamprey introduced a new aspect of the problem in that no direct effect on the metabolism of the animal can be involved. The sensory perception of the stimulus may result, however, particularly in an animal that has not fed, in glandular activity in the digestive tract. This reaction may in turn affect metabolic processes through changes in the blood. There is, however, no evidence to support such speculation.

The fundamental problem posed by the action of a chemical sensory stimulus is that of its "clock-setting" effect. The perception of the chemical stimulus not only results in a change in the activity rhythm during the 24 hours immediately following the stimulus but it also brings about the cyclic recurrence of the new rhythm. In this sense the problem is similar to that posed by chemical substances affecting the metabolism of an organism. The administration of such substances can produce modifications of a diurnal physiological rhythm which can recur at set times of the day in spite of variations in the amount of the substances applied (Bühnemann, 1955). The fact that sensory perception alone can bring about a modified and cyclic rhythm under otherwise constant conditions points to the central nervous system as the site of the clock-setting mechanism if not of the "clock" itself. Further work is aimed to investigate this aspect of the problem.

ACKNOWLEDGMENTS

The study is being supported by the National Research Council of Canada and McMaster University. It would not have been possible to undertake much of the research here reported without the financial assistance received during 1958 and 1959 from the Toronto Anglers' and Hunters' Federation. The authors are also indebted to the Department of Land and Forests, Division of Research, for assistance received in the course of this work.

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SHORT PAPERS AND NOTES

Longevity of the Horseshoe Crab, *Limulus polyphemus* (L.)

The horseshoe crab, *Limulus polyphemus* L., was studied in Plum Island Sound, Massachusetts, and other nearby estuaries that empty into Ipswich Bay. During 1952 to 1954, metal disk tags were attached to 1,778 crabs to obtain information about their life history and migratory habits. Since publishing the results of this study (Baptist, Smith, and Shuster, 1957) the authors have received additional tags (Table 1). These recoveries do not alter the general conclusion of the above publication, "... that there is a fairly discrete generation of horseshoe crabs in Ipswich Bay." The tags recovered to date do, however, provide the longest known record of the longevity of adult horseshoe crabs in their natural habitat (Table 2).

Although only 7.3 percent of the 1,778 tagged horseshoe crabs have been recovered to date, the seven individuals caught 4 to 6 years after release permit an estimate to be made of the adult life span of *Limulus* (Table 1). Shuster (1950, 1954) has estimated that *Limulus* spends 9 to 12 years as an immature individual, molting more than once a year during its early life history and annually after the third or fourth year. Upon reaching sexual maturity, however, adults are believed to cease molting (Shuster, 1950, 1954¹). Since the molting behavior might permit tags to be shed for the longest period of time on

adult crabs, 1,711 of the total number were selected as being adult individuals. The separation of immature from mature individuals required different criteria for each sex. To obtain 848 adult males, we examined the second pair of appendages for the presence of clasping claws which do not appear on immature males. To obtain 863 adult females, we looked for large orange or gray-green ova at the site where a hole was pierced with an awl to insert the tag. Immature females have either small white ova, or none. Although these criteria were useful in separating mature from immature crabs, it was not possible to determine when the crabs had become mature. Most of the crabs had probably matured considerably before tagging since many had hard shells and carried extensive encrustations of organisms such as barnacles and algae. A conservative estimate, therefore, of the adult life span of the individuals caught 4 to 6 years after release would be 5 to 7 years.

These few data do not give conclusive proof of the adult life span of *Limulus*. Although the sharp decrease in tag recoveries following the third year after release could be due to an average adult life span of 3 years, it is more probable that the decrease is due to a loss of tags. Natural mortalities and the deterioration of the pin used in tagging undoubtedly account for some tag loss. Natural mortalities were seen after severe winter storms when large numbers of dead crabs were found washed onto the beaches of Plum Island. The nickel tag pin is subject to corrosion and abrasion as tagged individuals burrow and plow through the sediments in search of food and spawning sites. The loss of tags could, there-

Shuster, C. N., Jr. (1954) On morphometric and ecological relationships within the Limulidae, with particular reference to *Limulus polyphemus* (L.). Ph.D. thesis, General University Library, New York University.

1.—Five tag recoveries of *Limulus* during 1957 and 1958

Release				Recovery		
Date	Sex	Size (millimeters)	Location	Date	Location	Recovered by
June 25, 1952	F	155	Point Peter	June, 1957	Eagle Hill River	N ¹
July 25, 1952	F	157	Point Peter	July 24, 1957	Third Creek	A
July 27, 1952	M	131	Nelsons Island	June 7, 1958	Newbury town wharf	N
May 15, 1954	F	144	Conomo Point, Essex ²	May 28, 1957	Staceys Creek	A
May 19, 1954	F	157	Point Peter	May 2, 1957	Cape Ann Fisheries, Gloucester ²	N

¹ = accidental recoveries by "non-alerted" visitors to the seashore; A = recoveries by "alerted" persons who searched for tagged crabs within Plum Island Sound.
² = released or recovered outside of Plum Island Sound.

TABLE 2.—Total number of tags returned, and years between release and recovery of marked horseshoe crabs

Years after release	Males	Females	Total
0	9	7	16
1	18	38	56
2	13	15	28
3	9	14	23
4	2	2	4
5	0	2	2
6	1	0	1
Total	52	78	130

fore, be substantial, although the extent of loss is unknown.

In summary, *Limulus* can have an adult life span of 5 to 7 years and, on the basis of estimates of its immature life span, a total life span of 14 to 19 years.

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Differential Sex Mortality
Associated with Handling
Landlocked Alewives¹

In 1958-59 experimental introductions of the landlocked alewife, *Alosa pseudoharengus* (Wilson), were made in lakes of the Adirondack region of New York as part of the fishery research program of Cornell University. Vincent (1960), in reporting on the operations in 1958, indicated that females suffered a higher mortality from handling than males. Because this loss might have an important effect on the success of introductions, an effort

¹ The author wishes to thank Dr. Dwight A. Webster for advice and review of the manuscript; and acknowledge the assistance of Messrs. William A. Flick, James A. Reckhan, and Carl L. Schofield in the field operations.

was made in 1959 to obtain information at this point. About 19,000 alewives were seined from Cayuga Lake, near Ithaca, New York, 14 days between June 19 and July 8, 1959. Six 4-hour and four 8-hour trips were made. Techniques used were similar to those described by Vincent. Number of females per 100 males at time of capture was determined for 12 separate lots by determining sex of 4,864 fish. Sex ratios were also established for the mortality occurring during handling (Table 1).

The number of females per 100 males varied erratically from 1 to 40 in successive samples with an average of 13. These limited data show no evidence of seasonal trends in sex ratio. On one occasion it was possible to check on variation within a single evening. On June 29 samples were taken from fish seined between 8:30 p.m. and 10:00 p.m. and those captured between 10:15 p.m. and 11:00 p.m. The number of females per 100 males in the first group was 22 while that in the latter was 4.

Mortalities during handling and transportation of nine lots ranged from 7 to 61 percent (Table 1). The lowest figure was on a group of green fish. The tenth lot was sorted so that only ripe females were carried. Of these 82 percent died on an 8-hour trip. Mortality appeared to be delayed several hours after seining. These findings corroborate those of Vincent in 1958.

Fish dying during transportation were sexed, and in every case the number

TABLE 1.—Sex ratios and mortality in various lots of alewives seined from Cayuga Lake, New York, 1959
[Figures in parentheses are number of fish sexed]

Date	Fish captured	Mortality (percentage)	Number of females per 100 males	
			Total sample	Deaths
June				
20,21	960	10	9(100)	21(42)
22	547	7	—	—
23	1,700	36	—	26(71)
24	2,500	40	36(265)	21(42)
25	4,088	24	6(495)	21(42)
26	500	—	2(229)	—
28	182	—	1(182)	—
29a ¹	1,904	42	22(138)	37(61)
29b ²	519	—	4(519)	—
30	1,700	61	9(1,700)	13(100)
July				
1	1,120	27	40(132)	96(100)
6	1,347	16	11(164)	22(42)
7	163	—	1(163)	—
8	778	82 ³	40(778)	—

¹ 8:30-10:00 p.m.
² 10:15-11:30 p.m.
³ 223 females only carried.

les per 100 males was greater than that of the original sample (Table 1). This differential mortality, coupled with the variation in ratios of the lots seined from Cayuga Lake, makes it advisable to sex fish during transshipping operations. The ratio obtained during seining can be corrected on the basis of the ratio in the mortality to reach an estimate of the number of females planted. In lots with a few females differential mortality might result in a few females being stocked, and since most fish are likely to die after planting, all females might die before spawning.

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Light Use of a Direct-Current Electric Shocker to Collect Trout in Lakes

Previous attempts to use a direct-current electric shocker to collect fish in lakes, without pulling the current, have been relatively ineffective (Haskell, Geduldig and Snoek,

1955; Loeb, 1955, 1958). At the Pigeon River Trout Research Station, Vanderbilt, Michigan, a direct-current shocker has been used in small trout lakes with considerable success. The collecting is done at night, from a boat. A Homelite direct-current generator (230 volts, 9.3 amperes) provides power both for underwater illumination and for an electrical field to attract fish.

Figure 1 shows the arrangement of the gear in relation to the boat. The ground, which is dragged by a halter from the stern of the boat, is a rectangular copper screen (24 by 28 inches) in an aluminum frame. Each of the two electrodes is a wooden dowel, 6 feet long and 1½ inches in diameter, with 1½ feet of the distal end sheathed with copper. A safety switch to control the electrode-ground circuit (the electrical field in the water) is fastened to the left side of the boat beside the oarsman. The frame to hold the lights is thin-wall electrical conduit (¾-inch diameter) bent to fit the contour of the boat. The two bulb sockets are of the swivel-type (to allow directional control of the light) and are attached to 4-inch junction boxes, which in turn are part of the thin-wall conduit frame. The light bulbs are protected by wire guards and also by the keel of the boat which extends below them.

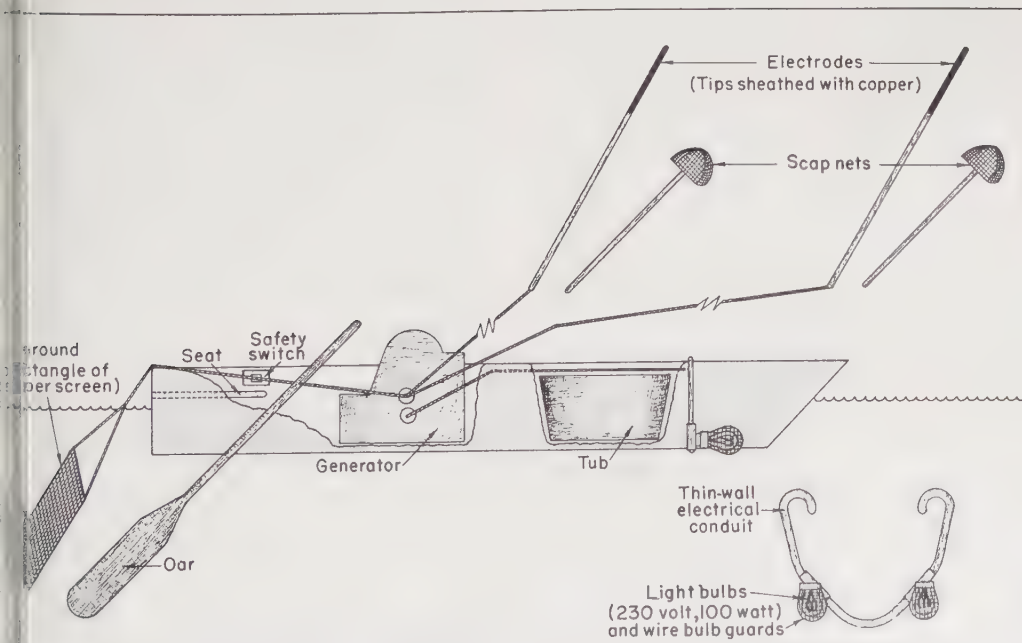


FIGURE 1.—Arrangement of gear in a boat for collecting fish in lakes at night.

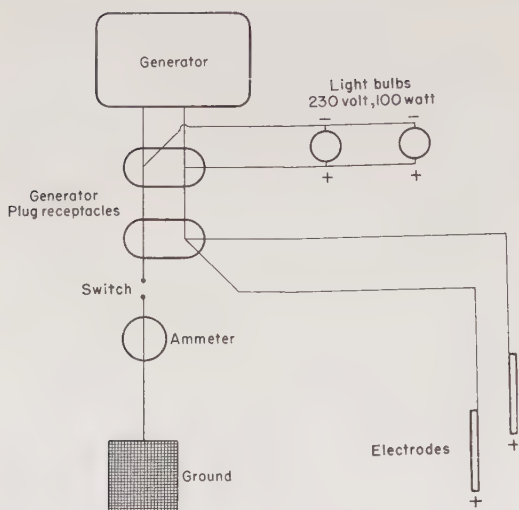


FIGURE 2.—Wiring diagram for the 230-volt direct-current generator which is the power source for the underwater lights and electrical field.

Figure 2 is a diagram of the wiring of the lights and the electrodes. For illumination, 230-volt bulbs (rather than the common 110-volt household type) are used. The two 100-watt bulbs are wired in parallel and plugged into one of the two generator plug receptacles, and the electrodes are plugged into the second receptacle. As a result, all circuits are in parallel and the voltage drop across each is the same. Although the generator is rated at 230 volts, the measured voltage was 240. The inside screw shell of the bulb socket is connected to the positive terminal of the generator in order to lengthen the life of the socket. If the center contact of the socket is connected to the positive terminal, it soon disintegrates by electrolysis.

When the gear was tested with both electrodes in the water near the bow of the boat, the ammeter (Triplett, Model 420, 0–15 D.C. amperes) in the circuit registered 3.2 amperes; when only the lights were in the water, the load was 0.2 ampere; but with both the lights and the electrodes in the water, it was still 3.2 amperes. Several trials on different days and in two lakes produced essentially the same results. The addition of the lights to the power source, therefore, did not decrease the strength of the electrical output used to attract fish.

In electrofishing with this gear, one man rows the boat. The generator exhaust is directed by a flexible pipe over the side of the boat. Two men, each with an electrode

and a scap net, stand near the bow and middle of the boat, respectively; the turtle hold the fish is between them. The oarsman is expected to open the switch to the electrode ground circuit if one of the operators is overboard, and, as a further precaution, the generator is not started until the lights are in position beneath the boat, the electrodes are readied, and both circuits are connected.

The water was clear in the lakes in which this gear was used. Nearly all fish were collected in water less than 6 feet deep, and no attempt was made to capture them. Some fish moved ahead of the boat to the outer edge of the field of light until they reached cover. They then stopped and became vulnerable to capture. The most effective method of collection was by use of a spearing approach, with the electrode in the water and a quick thrust when the operator was within range of a fish. A spearing or pooning approach frightened many fish of range. Upon being brought under the influence of the electrical field, usually within 1 foot or less of the electrode, the fish swam toward the electrode and could easily be taken to a scap net.

The two lakes in which the gear has been used contain only brook trout. Because there is no reproduction, the populations are maintained by annual fall plantings of fingerlings. These lakes are small in size but relatively deep (Ford Lake—10.6 acres, 29 feet maximum depth; Hemlock Lake—4.8 acres, 15 feet). The basin of Hemlock Lake is deep and has little shoal area. In contrast, half of Ford Lake is less than 5 feet deep. The experiments on these lakes included population estimates by the mark-and-recapture method during the spring and fall, when trout move throughout the lake and are accessible in shallow water.

The use of hoop nets was discontinued in these lakes because of their selectivity (Ward (1960) showed that many small fish are able to escape) and because this type of trap is difficult to set on the steep slope of the Hemlock Lake basin. Wire traps (made of ½-inch-mesh hardware cloth, triangular cross section, 33 inches on a side, 36 inches in length, funnel at one end, similar to those described by Lawrence (1952)) were as effective as hoop nets, but much less effective than the shocker. The superiority of the shocker over the wire traps for collecting trout was clearly demonstrated by the results of operations in the lakes in April of 1958.

1.—Number of brook trout captured with wire traps and with a direct-current shocker in Hemlock and Ford Lakes in April, 1958 and 1959

Lake and dates of collection	Gear	Fishing effort ¹	Brook trout collected		Estimated number of fish in lake
			Number	Range in total length (inches)	
Hemlock April 20–24, 1958	Traps	120 trap-days	217	5.0–10.8	1,000
April 22, 23, 29, 1959	Shocker	8 hours	514	5.4–12.4	700
Ford April 15–19, 1958	Traps	120 trap-days	327	4.9–13.4	2,000
April 20, 21, 27, 30, 1959	Shocker	12 hours	977	5.2–17.0	1,400

¹Fishing effort for wire traps is expressed as trap-days; e.g., in Hemlock Lake 24 traps were fished for 5 days, or a total of 120 trap-days.

(Table 1). In Hemlock Lake 5 days of trapping in 1958 with 24 wire traps (120 trap-days) resulted in a catch of 217 trout, ranging from 5.0 to 10.8 inches in total length from a population of about 1,000 fish. Approximately 8 hours of electrofishing at night in 1959 produced 514 fish, from 5.4 to 12.4 inches long, when the population was about 700 fish. Thus, in spite of the smaller number of fish in the lake in 1959, night shocking resulted in the capture of as many trout per hour as electrofishing (one trap-day being equivalent to 24 hours of wire trap set for 24 hours) in 1958. Similarly, in Ford Lake, night shocking in 1959 yielded as many trout per hour as 30 days of electrofishing in 1958.

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Abundance of Lamprey Scarring on Trout in the Upper Mississippi River, 1956–58

Depredations by the sea lamprey in the Great Lakes have aroused public interest in this parasitic fresh-water species of lamprey. In particular, questions arose concerning the

abundance, distribution, and effects of the parasitic species inhabiting the Mississippi River. In 1956 through 1958, the Upper Mississippi River Conservation Committee (UMRCC),¹ in the course of a cooperative survey of fish populations in the upper Mississippi River, directed special attention to the incidence of scarring by lampreys on fish taken during the survey. The parasitic species encountered were the silver lamprey (*Ichthyomyzon unicuspis*) and the chestnut lamprey (*Ichthyomyzon castaneus*). Both are native to the Mississippi River.

The section of the Mississippi River covered in surveys extended from Winona, Minnesota, to Burlington, Illinois, a distance of approximately 320 river miles. The 12 locks and dams located within this section are included in the river navigation system between Minneapolis, Minnesota, and Alton, Illinois. Each lock and dam is numbered and the reservoir above each dam is termed a pool and numbered correspondingly. Pools 6 through 19 were the bodies of water investigated. Trap nets, gill nets, trammel nets, and electrofishing gear were employed during the surveys of fish populations. In 1956 the States of Wisconsin, Iowa, and Illinois conducted a survey in pools 7 through 19. In 1957 the survey was limited to pools 8 through 13, with Iowa and Wisconsin cooperating. In 1958 a less extensive survey was conducted by the Wisconsin Conservation Department and covered pools 6 and 7.

Since some of the personnel who examined fish for lamprey scars did not have previous

¹The Upper Mississippi River Conservation Committee is an organization consisting of representatives from the Conservation Departments of Wisconsin, Minnesota, Iowa, Illinois, and Missouri; the Illinois Natural History Survey; the U. S. Fish and Wildlife Service; and the U. S. Army Corps of Engineers. The data in the present paper are extracted from progress reports of the UMRCC.

TABLE 1.—Incidence of lamprey scarring during 3 years of fishing surveys on the upper Mississippi River, 1956–58

Item	1956 (Pools 7–19)	1957 (Pools 8–13)	1958 (Pools 6–7)	Total
Number of fish scarred	21	14	33	68
Number of fish examined	14,483	13,954	3,548	31,985
Incidence of scarring (percentage)	0.1	0.1	0.9	0.2

experience, the problem of distinguishing a lamprey wound or scar from some similar traumatic or pathological condition was left to the judgment of the crew leader. In many instances lampreys, dislodged from their hosts, were found in the boat during netting operations. These specimens not only confirmed the more recent wounds, but also made possible the identification of species. Both parasitic species were identified. If the wound was not new, identification as a lamprey scar was determined from the condition and symmetry of the wound, and its location on the body of the fish. Errors were most likely to occur when identifying the older lamprey scars. Evidence of mortality due to lamprey parasitism was not observed.

INCIDENCE OF LAMPREY SCARRING

Lamprey scars or wounds were found on 68, or 0.2 percent, of 31,985 fish examined during 3 years of exploratory fishing (Table 1). The incidence of lamprey scarring in the lower pools during 1956 and 1957 was 0.1 percent for each year. Of 3,458 fish examined in pools 6 and 7 during the 1958 survey, 33 fish, or 0.9 percent, were scarred. Because of the nature of this study, the area surveyed, and the limited numbers examined in 1958, the increase is not believed to be indicative of a lamprey "pulse."

INCIDENCE OF MULTIPLE SCARRING

Of the 68 fish that were scarred by lampreys, 16 had multiple scars (Table 2). Attacks by two or more lampreys on an individual host fish have been reported in various waters of the upper Mississippi River. Forbes and Richardson (1920) found that paddlefish with two or three lampreys attached to a single fish were taken occasionally near Havana, Illinois. A commercial fisherman reported releasing a paddlefish with five or six lampreys attached near Trempealeau, Wisconsin, in the spring of 1959. There also have been authentic

TABLE 2.—Incidence of multiple lamprey scars on fish examined during 3 years of fishing survey on the upper Mississippi River, 1956–58

Number of scars per fish	1956 (Pools 7–19)	1957 (Pools 8–13)	1958 (Pools 6–7)	Number of fish scarred
1	17	10	25	21
2	3	2	4	14
3	—	1	3	33
4	—	—	1	—
5	—	1	—	—
6	—	—	—	—
7	1	—	—	—

reports of commercial fishermen who took fish from Lake Pepin with two or more lampreys attached.

SPECIES SCARRED BY LAMPREYS

Lamprey scars or wounds were observed on 17 species of fish during the 3 years of fishing surveys (Table 3). More than one-third of the fish scarred were northern pike. Black crappies, carp, and spotted suckers were next in the order of numbers affected. All of the black crappies which bore scars were taken in one trap-net set in pool 6. Although the numbers of northern pike attacked were relatively high, the silver and chestnut lampreys do not appear to be restricted in their selection of hosts.

The writer has on several occasions observed lamprey parasitism in the upper Mississippi River on species other than those listed in Table 3. These species were white sturgeon (*Acipenser transmontanus*), shovelnose sturgeon (*Scaphirhynchus platorhynchus*), channel catfish (*Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieu*),

TABLE 3.—Species scarred by lampreys during 3 years of fishing surveys on the upper Mississippi River, 1956–58

Species affected	Number affected
Northern pike (<i>Esox lucius</i>)	17
Black crappie (<i>Pomoxis nigromaculatus</i>)	4
Carp (<i>Cyprinus carpio</i>)	3
Spotted sucker (<i>Minytrema melanops</i>)	1
Northern redbreast (<i>Moxostoma macrolepidotum</i>)	1
River carpsucker (<i>Carpodacus carpio</i>)	1
Carp sucker (<i>Carpodacus</i> sp.)	1
Bighorn buffalo (<i>Ictiobus cyprinellus</i>)	1
Brown bullhead (<i>Ictalurus nebulosus</i>)	1
Largemouth bass (<i>Micropterus salmoides</i>)	1
Bluegill (<i>Lepomis macrochirus</i>)	1
Bowfin (<i>Amia calva</i>)	1
White sucker (<i>Catostomus commersoni</i>)	1
Yellow bullhead (<i>Ictalurus natalis</i>)	1
Flathead catfish (<i>Pylodictis olivaris</i>)	1
White bass (<i>Ambloplites rupestris</i>)	1
Freshwater drum (<i>Aplodinotus grunniens</i>)	1
Total	33

), and the walleye (*Stizostedion vitreum* (L.)). The lamprey attached to the smallmouth bass was identified as the silver lamprey.

Forbes and Richardson (1920) found the alewife or spoonbill (*Polyodon spathula*) to be the most commonly affected species in Elton-Grafton, Illinois, section of the Mississippi River. In the Havana, Illinois, area species preference was listed as paddlefish, alewife, and carp.

The findings summarized here lead to the conclusion that the parasitic fresh-water species of lampreys are not detrimental to the populations of the upper Mississippi River. The incidence of lamprey scarring on fish captured during the surveys was insignificant.

ACKNOWLEDGMENTS

Special thanks are due personnel of the Iowa, Illinois, and Wisconsin Conservation Departments, and the U. S. Fish and Wildlife Service, who have contributed to this report. The writer is particularly indebted to Dr. Robert E. Lennon, U. S. Fish and Wildlife Service, and Mr. John G. Brasch, Wisconsin Conservation Department, for their critical comments in the preparation of this paper.

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REVIEWS

CURRENT BIBLIOGRAPHY FOR AQUATIC SCIENCES AND FISHERIES. Compiled by Food and Agriculture Organization, Fisheries Biology Branch, Rome, Italy. Taylor & Francis Ltd., London, England. Published in parts. \$27.00 (per volume of 12 parts).

One of the important research aids in the field of fishery biology is this annotated bibliographic journal issued by the Food and Agriculture Organization of the United Nations. Formerly issued in mimeographed form, it appears in a printed edition in a more attractive and compact format beginning with Volume 3, 1960, and is to be issued in 12 parts to a volume.

In 1955 the FAO Fisheries Biology Branch began to examine and abstract scientific literature pertaining to fisheries resources for use by the staff of FAO. To broaden the coverage, assistance was received from research institutions, regional fisheries organizations, and others. A mimeographed document was begun in 1958 for exchange with the collaborators, and distribution of this document increased to the extent that FAO decided to print and publish the list in 1960 for general distribution on a subscription basis. According to the compilers, the publication is still prepared primarily as a document for internal use by FAO but the usefulness of the bibliography extends to anyone interested in research in the field of fisheries science.

This bibliography is limited in general to documents on studies of living aquatic resources and their environments, or to methods of research in this field. It includes references to both marine and inland (fresh) waters, each designated by an appropriate symbol. The two parts of Volume 3 that have appeared contain a total of 1,236 entries, the second part containing also the current indexes covering the first two issues.

References are selected from various sources, including documents, books, theses and dissertations, abstracts, other bibliographies, etc. Certain periodicals are indexed completely, while others are only partially indexed depending on subject matter. The references are serially numbered but not entered in any particular order, although references from a single publication are entered in order of appearance in the issue. If some formal arrangement of the entries, by subject or other grouping, were adopted, the material would be more readily accessible in issues received prior to the indexes. The annotations are concise and well done. Other helpful features are the translation of titles and language symbols.

The current indexes, consisting of author, geographic, taxonomic, subject, and citation sections, are comprehensive but are to appear only in part of the issues of a volume with annual indexes to follow. The index sections are arranged alphabetically or by classification and code. The subject index follows a special subject code pending the completion of the revised *Decimal Classification for Fisheries Science* which is being prepared by FAO. Guides to the classifications and codes used in the current indexes appear in the explanatory notes in Part 1, 1960.

The use of this extensive reference list is not limited to fishery scientists. Other research workers and especially librarians will find the bibliography

useful. The compilers state that they plan a more comprehensive publication eventually, but this serves as an excellent guide to the current scientific literature pertaining to fisheries resources and application of fisheries science.

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THE FRESHWATER FISHES OF CANADA. By E. S. Staltenenko. The Author, 132 Hillsdale Ave., Toronto 7, Canada. 1958. 385 pp., 138 figures, 1 table. \$15.95.

Dr. Staltenenko, who came to Canada from Europe about 10 years ago, has privately published this volume which attempts to treat all of the freshwater fishes of Canada. If his efforts have been less than successful it has not been for lack of painstaking work. The treatment is classical, consisting of a lot of synonyms, morphologic description, distribution and life history data. There are keys to families, genera, and species.

It should be emphasized that this work is largely an uncritical compilation in which free use was made of the few regional works currently available in various parts of Canada. One expects a certain amount of sifting and evaluating in a work of this type but there are too many cases of unnecessary repetition due primarily to the author's lack of familiarity with the fauna and those working with it.

The nomenclature deviates widely from current usage, reflecting perhaps the fact that the author has not been in close contact with working ichthyologists. More subspecies have been recognized than is usual among contemporary workers and listed, for example, are three subspecies for *Salmo gairdneri*, two for *Salmo salar*, three for *Leucichthys nigripinnis*, and three for *Coregonus clupeaformis*.

There are two pages of errata which do not include all the errors. In addition there are errors in spelling, typography, and omission. There are also many errors in the distributions. The illustrations have been reproduced from other publications with great loss in quality. A detailed listing of errors, many of which could have been eliminated by more critical reading of the manuscript, is considered unnecessary.

The wonder, however, is not that there are so many errors but that there are so few. The author has overcome a serious language barrier and gathered together a tremendous amount of information about the Canadian freshwater fish fauna, all in a few years. From this point of view the book is perhaps a personal triumph for the author. He was, however, ill-advised to go to press, for the high price is of all proportion to the value of the publication. Authors aspiring to works of this type should seek the closest possible association with institutions housing pertinent collections and the records, libraries, and other facilities associated with the work.

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MARINE FISHES OF RHODE ISLAND. By Bernard Gordon. *The Book & Tackle Shop, Watch Hill, Rhode Island.* 1960. 136 pp., 1 fig., 77 plates, 5 pls. \$4.00.

Marine Fishes of Rhode Island appears to be hurriedly prepared publication that reached the printer and printer before the manuscript had been fully edited for mistakes of classification, punctuation, inconsistencies, and general careless writing. It would be impractical to list all of the errors, but they will be readily apparent to the trained reader. Unhappy phrases and participles provide poor constructions. For instance, on page 26 we read, "This was also found September 19, 1957, at Wee-wee, using rotenone." The following sentence on page 59, "Trawlers and trap fishermen considerable quantities of sea bass along with ground line fishermen." There are others.

Unfortunately that the author did not consult the American Fisheries Society's Committee on Names of Fishes. Approximately 75 differences exist in classification, spelling, and general treatment of scientific names between the 215 species recorded by the author and the listing of the same in the American Fisheries Society Special Publication Number 2. Some may represent honest differences of opinion, but others are simply errors. Some of the common names also differ from those listed in the American Fisheries Society list. Some differences are apparently unavoidable, but they deserve better coordination.

The book is organized with a taxonomic listing of genus, species, and several common names for each recorded species. Below each species is a general section entitled *Specimens* with comments regarding abundance, size, range, migrations, and habits of fishing. Comments about the economic importance are included for most species. It is the reviewer's opinion that more care could have been taken with these sections.

The 77 plates are photographs taken by the author. They have been included for the photograph's sake rather than any utility to the publication.

The reviewer would not be nearly so enthusiastic about the Foreword regarding groups that would find the book of value. It is an annotated checklist of value, for example, as a handbook to identify

fish and in an attractive cloth binding, the book is printed on good quality paper with an easily read type. Indices of both common and scientific names are included.

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THE NATURE OF PRODUCTION IN THE SEA. By H. Cushing. (*Great Britain Ministry of Agriculture, Fisheries and Food, Fishery Investigations, Series 2, Vol. 22, No. 6*). Her Majesty's Stationery Office, London. 1959. 40 pp., 13 figs., 17 tables.

This article has two main themes. The first is the development of a generalized theory of population dynamics in the sea; the second is a critical examination of present methods of measuring standing crop and the various physiological processes that

enter into the evaluation of population equations. The form of these equations will be familiar to students of population dynamics. They stem from the Volterra prey-predator equations, which are then modified in various ways to make them applicable to the different trophic levels.

For example, the local time rate of change of inorganic nutrients is postulated to depend upon the degree of balance between regeneration (bacterial activity, zooplankton excretion) and utilization by phytoplankton. Similarly, equations for phytoplankton and zooplankton express a balance between daily reproductive rate and losses due to predation and natural mortality. In the case of herbivore-feeding and fish-feeding fishes, the reproductive term is replaced by an expression representing the difference between immigration and emigration rates in the area in question. It is not explicitly stated whether this refers only to migration or also includes reproductive recruitment. In practice it probably would not be possible to deal with a whole trophic level of fishes as a unit, and presumably the ultimate form of such equations would depend on individual species habits.

The discussion of population theory will be valuable to new workers in the field, since this is one of the few papers that gives a relatively complete account of the theoretical approach to the whole productive cycle in the sea. More experienced investigators will find little that is new in the theory *per se*, and their chief interest will be centered in Cushing's discussion of the problems of applying mathematical models to the natural environment. He discusses in some detail his method of estimating diatom division rates from decrease in cell size and relates division rate to light penetration. The method suggests a possible alternative to the more common measurements of C^{14} uptake and oxygen production. Previous work that he has done on the natural mortality of diatoms, based on counts of empty frustules, is briefly discussed.

Of particular interest to many of us is Cushing's analysis of copepod grazing rates. Experimental measurements of grazing rates have varied widely, many of them being too low to be credible, in that they would not provide enough food for the animals to exist in nature. Cushing has demonstrated that grazing rates are markedly dependent upon the volume of the experimental container, and we must conclude that all experiments done in small containers are suspect for this reason. He proceeds then to develop an "encounter theory of grazing" which states in effect that copepods unimpeded by small containers can catch diatoms on their antennules and consume them while underway at full speed, thus greatly augmenting the catch obtained by the more commonly recognized filtering method. The reader is left in some doubt as to whether this theory is a satisfactory explanation of the experimental results. Nevertheless, it is a theory that is susceptible to further development along quantitative lines, and the results lead to a fairly realistic model of spring diatom growth and grazing effects in the North Sea.

Other sections deal with nutrient balance and with problems of organic production in oceanic waters, particularly the Sargasso Sea.

This is a paper that raises more questions than it answers and leaves the reader with something of a feeling of frustration because we still know so

little about many of the problems that will have to be solved before we can have a clear concept of the dynamics of plankton production. However, it is an important paper which deserves careful and thoughtful examination by other investigators in the field.

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caused by"), and 517 ("variety of usually high specific stimuli").

In conclusion, this volume is one that a student research worker interested in the Crustacea will find a valuable addition to his personal library. The reviewer hopes that Volume II, which will deal with sense organs, integration, and behavior, will meet the high standards of Volume I.

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THE PHYSIOLOGY OF CRUSTACEA. Edited by Talbot H. Waterman. Vol. 1, Metabolism and Growth. Academic Press, New York. 1960. 670 pp., figs., tables. \$22.00.

This first of two volumes on the subject of crustacean physiology will be welcomed by many biologists. For the first time an attempt has been made to systematize and evaluate in detail the vast amount of information on this broad subject. The selection of writers for the 17 chapters in the first volume was especially appropriate; each is a specialist in the particular area reviewed.

It is apparent from reading the volume that in spite of different writing styles the contributors adhered to a basic plan that lends a desired unity to the volume. The first chapter will be especially useful to physiologists. In this chapter Waterman and Chace discuss the diagnostic features of the Crustacea, their morphology, development, ecology, systematics, and evolution. Some of the other chapters deal with such varied topics as respiration, circulation and heart function, blood, biochemistry of pigments, feeding, osmoregulation, terrestrial adaptations, sex determination, regeneration, and molting. Considerable morphological detail is included in the volume with the result that the reader obtains a fuller understanding of the functional aspects. Although 3 years were expended in preparation of the volume, many of the chapters contain references to material published in 1958 and 1959.

Students wishing to undertake a research problem will have no difficulty selecting one from the multitude presented by the authors. That the contributors presented not only factual material but also possible areas of future research is one of the highlights of the volume. The reader becomes immediately aware that the Decapoda comprise the only group of Crustacea that has received its proper share of attention by research workers. Great gaps exist in our information concerning the remaining Crustacea. The chapter on sex determination by Charniaux-Cotton is one that should be singled out as especially well done and particularly timely in view of the rapid advances being made in this area.

The numerous illustrations are excellent. The indexing is also superb. An author index, systematic index, and subject index are included. Much effort must have also gone into preparation of the many useful tables. Examples of some of the tables are: oxygen consumption, respiratory quotient, Brachyuran intermolt stages, osmotic pressure of blood and urine, and blood protein concentration. The volume contains very few typographical and grammatical errors. This reviewer detected four that should be corrected if the volume is reprinted. These errors occur on pages 297 ("There are no indication"), 510 ("hormone acts solely control the"), 513 ("loss of metabolic control

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NINETIETH ANNUAL MEETING
of the
AMERICAN FISHERIES SOCIETY

DENVER, COLORADO

SEPTEMBER 12-14, 1960

NINETIETH ANNUAL MEETING

AGENDA

Monday, September 12

Morning: Call to order by President James W. Moffett; address of welcome by Dr. Edward L. Clark; opening remarks by President Moffett; determination by Secretary-Treasurer that quorum was present; appointment of Sessional Committees by the President; report of Secretary-Treasurer; report of Membership Committee; action on nominations for membership; report of Finance Committee; report of Librarian; reports of chairmen of Regional Divisions; report of special Committee on Professional Standards; report of Committee to Study Pros and Cons for Future Meeting Associations; report of *ad hoc* Committee to Study Advisability of Hiring Executive Secretary; reports of Standing Committees.

Afternoon: Reservoir Management Session, James T. Shields, chairman; Miscellaneous Session, Howard A. Tanner, chairman. Presentation and discussion of papers.

Tuesday, September 13

Morning: Insecticides and Toxicants Session, Jack Hemphill, chairman; Fish Culture Session, E. T. Rose, chairman. Presentation and discussion of papers.

Afternoon: Presentation and discussion of papers, Kenneth Carlander, chairman; concluding business session; other committee reports; election of officers; installation of new officers; concluding business.

Wednesday, September 14

Morning and afternoon: Air Force Academy trip.

Evening: Annual banquet in the Grand Ballroom, Denver Hilton Hotel, held jointly with International Association of Game, Fish, and Conservation Commissioners.

BUSINESS SESSIONS

Opening Business Session

The 90th annual meeting of the American Fisheries Society convened in the Junior Ballroom of the Denver Hilton Hotel, Denver, Colorado, Monday morning, September 12, 1961, and was called to order at 9:30 a.m. by President James W. Moffett, who then introduced Edward L. Clark, Director of the Colorado Department of Natural Resources, to give the address of welcome. After completion of the welcoming address and announcements concerning the program of the meeting, Mr. Moffett made the following remarks:

It is indeed an honor to deliver the president's remarks at the opening of the 90th meeting of the American Fisheries Society. I am proud to be a part of this organization since it is a pleasure to me a great personal benefit to be associated with all of you. Your typically constructive, yet optimistic, attitude and your desire for progress have characterized the year since I was escorted to the rostrum in Clearwater, Florida. Besides your attitudes I have noted an encouraging tendency to fundamentalism and vigor of inquiry in professional ranks.

During visits to the meetings of the North-Central and Western Divisions, great capability and enthusiasm were evident. Everyone seems anxious to work for the advancement of the Society, and more important, for the achievement of its major objectives. Generally, there is a feeling that the Society is doing its job. Optimism for the future seems to be the rule.

Since its organization, the American Fisheries Society has sought diligently and with considerable success to solve fishery problems as they have been presented them. These problems have changed with the growth of the country and with the interests of the people. Fortunately, the Society has been able to change with them, not in a series of starts and stops, not as a result of crisis after crisis, but after sound deliberation, study, and reflection. The more impatient among us would have had some of these changes come more promptly. However, none of us are too dissatisfied with the final outcome on some rather difficult issues.

This year's operation has not been without its tribulations. We are plagued with growing pains. Like any other groups similar to ours, we have reached the point where some of the things we have done and are accustomed to, must be put aside and new and greater responsibilities must be taken up. We are not quite big enough to handle some of these jobs and new services, although we envy the big brothers who have just what we want. Indeed, we are presently like the boy entering puberty, one minute we speak and act like a child, and the next minute we thunder like the basso of manhood.

Because we are growing, our responsibilities are stacking up. Whether we like it or not, the business of this Society is going to demand more

than your elected officers can carry. Eventually, we must have a business office with efficient business methods, preferably in or near Washington, D. C.

The handling of our publications alone is becoming a big job. We have more and more need for contact with other societies, government agencies, and research organizations. We must hold up our end in the challenging culture of North America. Yet we should not, moreover we cannot, accommodate all of these needs immediately. The Finance Committee has recommended that we stabilize our position at all times before we move ahead. This approach is logical and represents a policy that has seen the Society through some trying times. All of us must work to increase the membership of the Society so that the housekeeping and the service we want can be financed. All of these needs we will eventually fill, but in doing so, we should never lose sight of the objectives of the Society. These are the things that bring us stature, respect, and professional recognition.

To refresh your memories, I shall take time to read the preamble to the constitution which sets forth the objectives of our group. [Preamble to the constitution of the American Fisheries Society read.] Perhaps these objectives are now not adequate to some of you. But, if so, they can be amended by orderly procedure and by action of the Society. To me they set forth a responsibility that will require all of our energy to fulfill.

I want now to express my sincere and deep gratitude to all of you who have served in this year's slate of officers. You have been untiring and unselfish in your efforts. To the Program Committee especially and to the State of Colorado go thanks *magna cum laude*. We are going to have a wonderful and constructive meeting, thanks to all of you.

At the conclusion of the President's remarks, Secretary E. A. Seaman declared that a quorum was present.

President Moffett then appointed the following sessional committees: *Nominating Committee*—Albert H. Swartz, *Chairman*, W. Mason Lawrence, John Funk, Robert G. McMynn, Robert E. Schumacher, and Robert Martin; *Resolutions Committee*—Robert M. Jenkins, *Chairman*, Alex J. Calhoun, Eugene W. Surber, George J. Eicher, James P. Galligan, and J. Frances Allen; *Publicity Committee*—James R. Harlan, *Chairman*, George Eicher, and Lewis R. Garlick; *Time-and-Place Committee*—John S. Gottschalk, *Chairman*, H. S. Swingle, Fred Locke, Cliff Millenbach, and James T. Shields; *Auditing Committee*—Orty E. Orr, *Chairman*, Richard Whiteleather, and Alex J. Calhoun.

Secretary Seaman presented the report of the Secretary-Treasurer, in which he pointed out the increasing duties of the secretary's office and outlined the financial position of the Society. Slow payment of dues has been one of the major problems in successfully maintaining the financial status of the Society. The change to annual billing from the fiscal year billing was described. He pointed out that the grant from the National Science Foundation made possible the printing of Special Publication No. 2. The financial condition of the Society is expected to be better at the end of the next calendar year than at present, through the elimination of nonrecurrent expenses. Secretary Seaman presented the suggestion that the Society approve a distinctive emblem which would be available to members by purchase from the Balfour Jewelry Company. Such approval would entail no financial responsibility to the Society. The Secretary moved the report be accepted. The motion was seconded by Albert S. Hazzard and carried.

Kenneth D. Carlander presented the following report of the Membership Committee:

The Membership Committee has worked hard, and of the five or six membership committees of the Society on which I have served, there was more correspondence this year than in any previous year. Among the activities of the committee, some should be mentioned. Membership tables were set up at several of the regional meetings to inform people of the Society and to sell membership. Letters were sent to several special mailing lists. Heads of research organizations were contacted and brought in quite a number of memberships.

The Wyoming Department of Fish and Game took out 17 memberships for their fish hatcheries and fishery management stations. This practice was recommended to all other states. Utah followed suit. Maine and some other states pointed out that their biologists also were already members. When a member leaves an organization, he can be expected to take his file of *Transactions* with him, and when a young man comes in the hatchery or station there is no permanent file of the *Transactions*. It is hoped that more states can follow a program of promoting stations with *Transactions*, but some cannot because they are legally bound.

Although library memberships increased to 155 with 36 of these being new members during the last year, this number is still far below what it should be. Several journals have about 400 library members, three times what we have. Letters have been sent out in the last year to over 400 libraries but we need help on the local level. If each of you would ask for the *Transactions*, your library may order them.

During the year it looked as if membership would drop seriously, partly because our system of dropping members after 2 years' delinquency

resulted in the loss of a good many that have not paid since the dues were raised to \$10. We can report, however, that as of August 31, 1960, there is a net gain of six over a year ago. This is merely holding our own. The membership is now 2,073, but most experts say that we must have at least 3,000 to consider hiring an executive secretary.

Dr. Carlander moved and Samuel J. Hudson seconded the motion that the report be accepted. The motion was carried.

Seth Gordon presented the following report of the Finance Committee:

In view of the fact that the Finance Committee last year made such an exhaustive report, this year's committee decided not to submit a formal report at this time. It was recommended to the Executive Committee that until the members of the Society have had further opportunity to study and observe the operations of the Society under the present fee schedule, the publication of the *Transactions* on a quarterly basis and the registration fee plan at the annual meetings, the Committee should refrain from submission of further fee proposals at this time.

The Committee also reviewed the problem which have arisen when copies of the quarterly *Transactions* are mailed to members who are delinquent, and recommend that a notice go out on the mailing of the quarterly 90 days in advance of the date when dues are payable, calling attention to the fact that further mailings will be discontinued until dues are paid for the ensuing year, such notice to be included either in the *Transactions* or by letter or both, as may be found desirable.

Mr. Gordon made a motion that the committee report be approved. It was seconded by Clarence F. Pautzke and passed.

Howard Tanner then presented the following report of the librarian:

This report covers the period from September 1, 1959, through August 31, 1960, during which period the following sales and distributions of volumes have occurred. While no detailed listing will be presented, they included the index and the various classifications of the volume, the new quarterly numbers, occasionally odd volumes, special publications numbers 1 and 2, and the new publication on technical writing. The sales totaled \$2,681.50. The amount of \$690.00 outstanding on orders recently submitted. I paid invoices which we do not expect to collect total \$473.50. All volumes preceding number 1 are out of print. This year we received \$124.00 as royalties from the J. S. Canner Company, Boston, Massachusetts, for their microcard reproduction sales.

As you all know, the volumes are no longer stored in my care. For purposes of economy and consolidation, we have transferred the functions of the librarian to the secretary in Washington, D. C. I am highly in favor of this move for several reasons. One of them is the certainty of economy effected, and also, 8 years is a long time. I have served you with a good deal of pleasure, and I believe this will be my last report.

anner moved that the report be accepted. The motion was seconded by Frederick A. Hapson and passed.

Andrew H. Hulsey, in lieu of a report of the Western Division, stated that the 1960 meeting would be held on October 23-26 at the La Vista Hotel at Biloxi, Mississippi, and all committees had been appointed and the program was complete. He moved adoption of the report. It was seconded by Minor Mark and passed.

The report of the Northeastern Division was adopted by John M. Cronan as follows:

The annual meeting of the Northeast Section, American Fisheries Society, was held in Providence, Rhode Island, on January 10-13, 1960. The 1960 Northeast Wildlife Conference, which included the Fisheries Society section, was sponsored by the Rhode Island Division of Fish and Game, and there were over 400 people in attendance. The major topics of the 3-day formal program included sessions concerning (1) subsistence and speciation; (2) population parameters and interspecific relations; (3) hydrology and culture of aquatic organisms. Some innovations from the conventional program were incorporated into this meeting. The new features included a second general session which covered topics of interest to both fish and wildlife personnel. Secondly, active participation by marine and freshwater scientists was obtained and the resulting exchange of information with fresh-water workers was mutually beneficial.

Seventy-three members were present at the business meeting. Although new resolutions were entertained, they were not formally passed by the voting body. Newly elected officers for the forthcoming year were: chairman, Lyndon H. Rod, Maine; vice-chairman, J. Carl Medcof, New Brunswick; and secretary-treasurer, Robert Rupp, Maine. The next meeting of the Northeastern Division is tentatively scheduled for Nova Scotia. No firm date for this meeting has been established.

Cronan moved that the report be adopted. The motion was seconded by Gerry Wade and passed.

Robert E. Schumacher presented the report of the North-Central Division as follows:

The fourth annual meeting of the North-Central Division of the American Fisheries Society was held at the Hotel Leamington in Minneapolis, Minnesota, December 7-9, 1959, in connection with the 21st Midwest Wildlife Conference. Approximately 70 members of the division were present at the business session, December 8, 3:30 P.M. Guests present included James W. Moffett, members of the Wildlife Society, Sport Fishing Institute, U. S. Fish and Wildlife Service, and fisheries workers from Saskatchewan.

Brief discussions of the possibility of closer working relationship with other wildlife management organizations were presented by Jerome Lehn of the Minnesota Department of Conser-

vation, and an estimation of costs involved in hiring an executive secretary was presented by Lloyd L. Smith, Jr., of the University of Minnesota.

Papers concerning fisheries management and research were presented at the fisheries papers sessions in the usual informal atmosphere of the Midwest Wildlife Conference. Twenty-six presentations were made covering a wide variety of topics from fisheries of Cambodia to Minnesota and South Dakota. The papers presented were of high quality and the discussions following were lively and informative.

Reports were made by the Secretary of the minutes of the last annual meeting and by the Treasurer of the North-Central Division. The report by the Nominating Committee was made and followed by the election of officers for the succeeding year. Robert E. Schumacher, Minnesota Department of Conservation, was elected chairman for 1960, William C. Starrett, Illinois Natural History Survey, vice-chairman, and Orty E. Orr, Nebraska Game, Forestation, and Parks Commission, secretary. The Time-and-Place Committee of the Midwest Wildlife Conference, with which the North-Central Division of the American Fisheries Society holds its annual business meeting, chose Toronto, Canada, for the next annual meeting, to be held December 5-7, 1960.

A motion from the floor was made, seconded, and carried by majority vote to appoint a committee in the North-Central Division to assist a similar committee of the parent Society. The stated purpose was to determine the membership's attitude toward a closer affiliation with other organizations such as the Wildlife Society and to find out how the membership felt about hiring an executive secretary for the Society.

The Tri-State Fisheries Meeting of Michigan, Wisconsin, and Minnesota workers was not held this year due to a shortage of Game and Fish funds experienced by all three states. The postponed meeting would have been the 16th annual meeting of this group.

Mr. Schumacher moved the report be accepted. The motion was seconded by John Funk and passed.

Forrest R. Hauck presented the following report of the Western Division:

The 12th annual meeting of the Western Division of the American Fisheries Society was held in Salt Lake City, Utah, in conjunction with the 40th annual meeting of the Western Association of Game and Fish Commissioners on June 20-22, 1960. A fine program covering topics of fishery management, fish culture, and pesticides was developed by Program Chairman Donald Andriano. Dual sessions permitted a broader program and provided interest to a greater number of members. Problems of pollution, fish nutrition and diseases, and fish toxicants were included in the discussions.

The meeting was held at the Hotel Utah Motor Lodge. Meeting rooms were more than adequate and fine air-conditioning added much to the enjoyment of the meeting. Attendance of more

than 100 members was approximately double the number who attended the first provisional meeting of the Western Division in Salt Lake City 12 years ago. The attendance of President James Moffett and Secretary-Treasurer E. A. Seaman highlighted the meeting.

Next year's meeting will be in Santa Fé in conjunction with the 41st annual meeting of the Western Association of Game and Fish Commissioners. New officers elected to carry on the business of the Society were as follows: chairman, Forrest R. Hauck, Idaho Department of Fish and Game, Boise, Idaho; vice-chairman, Cliff Millenbach, Washington Department of Game, Olympia, Washington; and secretary-treasurer, Fred Locke, Oregon Game Commission, Portland, Oregon.

Mr. Hauck moved the report be accepted. The motion was seconded by Alex Calhoun and passed.

The report of the *ad hoc* Committee on Professional Standards was presented by Lloyd L. Smith, Jr. The report was highlighted by discussion of the return of questionnaires concerning problems of professional standards. These questionnaires indicated that the majority of members do not wish to have professional qualifications for membership in the Fisheries Society and that establishment of professional standards and accreditation of biologists by the Society are not generally desired at this time. Several recommendations were made, especially that membership in the American Fisheries Society not be based on professional standards and that efforts be made to set up a general criterion of professional standards which could be used by institutions training men and by hiring agencies interested in recruiting adequate personnel. Dr. Smith made a motion that the report be accepted. Eugene Surber seconded the motion, which was passed.

Secretary Seaman presented the report of the *ad hoc* Committee on Future Meetings with other Associations, as follows:

The committee to consider the pros and cons of annual meeting time, location, and the association with other organizations of the American Fisheries Society, composed of myself, the late William Harkness, and W. Mason Lawrence, conducted a correspondence on this subject. We found no justification nor significant reason for changing either the meeting time or the association with the International Association of Game and Fish Commissioners at this time. There are certainly some legitimate reasons that might be considered for moving the annual meeting. The academic men would like to have it moved because it cuts into the center of their fall registration on campus. This factor keeps many of them away from our meetings. Since there are many members who meet with the AIBS, Carl

Riggs suggested that there might be a program of the American Fisheries Society at the AIBS annual meetings.

The reason that the committee felt that the established meeting date should not be changed is the matter of economy. It costs a lot of money to meet with the AIBS, or with the International Association. Although this cost increases each year, it does not appear to be a significant reason for making a change. The Committee feels very strongly a sense of appreciation and thanks to the International for meeting with us over the many years. We have found this association good, and it is established as a very definite precedent.

Mr. Seaman moved that the committee report be accepted. Lee S. Roach seconded the motion, which was passed.

Raymond E. Johnson presented the report of the *ad hoc* Committee on Hiring of Executive Secretary, as follows:

In the past year informal studies have been made of many features of our Society's operation to learn just what the secretary-treasurer's office was doing and what the costs of operation were. Opinions on our ability to support a full-time executive secretary's office were also obtained from several organization specialists in the Washington area, and from executive directors of other professional groups.

The groups consulted included the National Science Foundation, the AIBS, the American Institute of Park Executives, the Society of American Foresters, the American Forestry Association, the Entomological Society, the American Chemical Society, the American Institute of Physics, the American Physical Society, and the American Society of Association Executives.

I regret to say that the studies begun this past year have not been completed and much remains to be done. This situation resulted in part from our having too much material to examine and too many contacts to make. It also resulted from the intrusion of new side-line questions into the main objective of our study. For example, the possibility of sharing a common executive secretary and staff with the Wildlife Society, or with the International Association, or with any one of a half dozen other groups, had to be investigated. Enough has been done, however, to give some tentative conclusions and for some recommendations at this time.

Based on the experiences of other organizations, it is apparent that our Society has reached the awkward size where it is not quite large enough to support a full-time secretarial staff and yet it is large enough to require continuing full-time attention to the administration of business and the requests of its members. We cannot rely on voluntary services any longer. Therefore it should be determined immediately whether or not the funds now spent on part-time help could be used better for the setting up of a small office, including the rental of minimum equipment and the purchase of some equipment and the hiring of at least one full-time clerical employee. This item is of first priority, and

tion should be made within a matter of weeks.

Next, the Society should determine exactly what services it can provide its members, what its members need and expect, and what the Society's goals are to be for the next 5 or 10 years. The feasibility of an executive-secretary position depends upon costs and the costs depend upon the services to be provided. The nature of these services is not yet firm, and we must decide within a few months what we want from an executive staff. As a part of this major determination, we must also decide whether these services can be given better or our objectives more fully achieved by merging our executive secretary with another society.

Almost every organization with which we consulted advised that haste be made slowly in these matters. You have also heard that from Dr. Smith's report, and from Mr. Gordon's report. The people with whom we consulted said that this was a time for reflection on our part and a time of stabilization in Society affairs, to let the actions of the past 3 years prove themselves. With that advice in mind, we recommend that when the Executive Committee meets again, which presumably will be in Washington, D. C., in March 1961, that it invite the Director of the African Society of Association Executives to come with us the steps we propose to take toward becoming a mature and purposeful, active organization. There is help of the highest professional type available in that association. We need it, and we ought to take advantage of it.

Johnson recommended that the report be adopted. The motion was seconded by Richard Croker and passed.

Edmond E. Johnson presented the following report of the Awards Committee:

Forty-two years ago, Mr. R. C. Osburn, who was then editor of the Quarterly, announced that a prize of \$100 would be offered for papers of special merit submitted to the quarterly journal. Again, one year later, three prizes were offered for leading articles under three subject headings. This award system failed in 1920 because the papers offered in competition had to be submitted one month in advance of the annual meeting date of the Society, to give time for careful consideration by the Committee on Awards. Few authors met the deadline.

The tradition was renewed in 1959 when a prize was awarded to a deserving author. This year recognition is given to papers already published in the latest complete volume of the *Transactions*, in the hope that more good papers will be attracted, the *Transactions* will improve in quality, and members of the Society will make better use of this journal.

An anonymous group of Society members, unknown even to each other, reviews each annual volume and selects the papers which in their judgment best meet certain criteria of excellence. The papers in volume 88 were examined. There were 49 major papers compared with 37 last year. The range of subjects covered was also greater and the job of judging was made more difficult. The opinions of addi-

tional reviewers were sought in an effort to get a larger panel and more experience into the judging.

Finally the many papers were narrowed down to one. Because of the rather unusual authorship arrangement of this paper, the Executive Committee approved the suggestion that a prize of \$75 be awarded and that it be divided among the authors of the paper.

The paper selected this year from volume 88 was "Destruction and re-establishment of stream fish and invertebrates affected by drought," by R. Weldon Larimore, William F. Childers, and Carlton Heckrotte. As chairman of this Awards Committee and the only man that ever appears in public, I would like to present to Dr. Larimore at this time the citations from the American Fisheries Society in recognition of this accomplishment. [Presentation accepted by Dr. Larimore.]

Lloyd L. Smith, Jr., presented the report of the Editorial Committee. He stressed the need for quality in papers and pointed out that 127 manuscripts had been reviewed during the year, comprising approximately 2,500 manuscript pages. Seventeen of these were rejected, the others have been published, returned to the authors for revision, or are on the editor's desk awaiting future publication. The editor recommended that long papers be accepted provided that authors or sponsors furnish the cost at going page rates for all papers exceeding 15 printed pages in length. The editor moved the acceptance of the report. Bernard T. Carter seconded the motion, which was passed.

The report of the Committee on Names of Fishes was read by James T. Shields. He reported that Special Publication No. 2 on the common and scientific names of fishes has been completed and is available to the membership. He made a motion that the report be accepted. Richard S. Croker seconded the motion, which was passed.

Edward Schneberger presented the report of the Committee on National-State Relations. The report pointed out that the federal government should concern itself primarily with problems which individual states could not handle. Many important areas of basic research extend beyond the scope of individual activity. Many problems exist which might be handled by interstate organizations. Especially acute are those relating to boundary-water regulations. A series of recommendations for national-state relations was presented. Dr. Schneberger moved that the report of the committee be accepted. It was seconded by Gerry Wade and passed.

Clarence Tarzwell presented the report of

the standing Committee on Water Pollution, and pointed out that a comprehensive survey had been made which was too long to present at the meeting but would be available through the secretary's office. It was further pointed out that cooperation by the states has been good and that increased attention to problems of pesticide pollution is being given by state agencies. There is also evidence of increased recognition of the problems of silt pollution, inorganic pollution, and general watershed pollution. Dr. Tarzwell moved the acceptance of the report. It was seconded by Max Katz, and passed.

President Moffett read the abstract of the report of the Committee on International Relations, which was chaired by William A. Dill of FAO. President Moffett moved its adoption. Alex Calhoun seconded the motion which was carried.

Frank F. Hooper presented the report of the Committee on Hydrobiology and Fish Culture. It covered the use of radioactive isotopes in fishery management and fishery research. A number of important uses were suggested which should stimulate research workers to further use of this important new tool.

Hooper moved the acceptance of the report. The motion was seconded by Peter Tack, and passed. [For full report, see pages 49-57.]

The report of the Committee on Commercial Fisheries was called for, but in the absence of the chairman, the draft was presented without discussion for inclusion in the published *Transactions*. The President directed that the report be accepted and published.

On motion from the floor to adjourn, the business meeting was recessed at 12 o'clock noon.

Closing Business Session

The concluding business session of the Society was called to order by President Moffett at 8:00 p.m. in the Junior Ballroom of the Sheraton Hilton Hotel, on September 13, 1960. In opening the meeting, the President related that the audience rise in silence to the memory of Dr. William Harkness who recently passed away after a brilliant career in fisheries.

Secretary Seaman introduced Mr. Walter H. Hile, representing the Boy Scouts of America, who presented a plaque to the American Fisheries Society from the Boy Scouts organization with the following remarks:

Friends, 1960 marks the Golden Jubilee of the Boy Scouts of America. Scouting and the conservation movement as we know it today started at the same time in the first decade of this century. Many of the pioneers in conservation were also pioneers in scouting. So it is only natural that we still look to the great conservation organizations and agencies across this country for guidance and help in formulating our conservation activities program.

The Boy Scouts of America are making this year an occasion to honor some of the organizations that have been most helpful over the years in our conservation programs. It gives us a great deal of pleasure to present sincere thanks and a forthcoming plaque to the American Fisheries Society, in sincere appreciation of the help in our national conservation program. President Moffett, we are grateful and hope that this plaque will let all your associates and all your affiliates know that in its Golden Jubilee year, the Boy Scouts of America gratefully recognize the American Fisheries Society for significant services to American boyhood through scouting.

President Moffett received the plaque for the American Fisheries Society and pledged continued support of conservation activities with the Boy Scout program.

President next thanked the local Program Committee for their efforts in organizing the 10th annual meeting. He also tendered thanks to the Publicity Committee headed by Mrs. R. Harlan.

President Moffett called for the report of the Time-and-Place Committee. The 91st annual meeting will be held at Memphis, Tennessee, on September 13-15, 1961, and the 92nd annual meeting will be held at Jackson, Wyoming.

At request from the president, O. E. Orr presented the report of the Auditing Committee. He stated that the records of the Society for the fiscal year 1959-1960 had been ex-

amined and that the report of Howard C. Haire, certified public accountant, dated August 4, 1960, showed the Society books and accounts to be in order. Mr. Orr moved that the report be adopted. The motion was seconded by Marion Toole and passed.

Edward Schneberger nominated H. H. MacKay of Toronto, Ontario, for honorary membership in the American Fisheries Society. He stated:

Dr. MacKay served as president of the Society in 1947 and 1948, and has served on many committees and has carried out many assignments. He was elected president at the Denver meeting in 1947, and therefore it is quite fitting to place his name in nomination at this time at this meeting for honorary membership. Dr. MacKay has been a loyal member, a willing worker, and has faithfully attended the meetings of the Society for many years.

Ralph Hile seconded the nomination which was adopted unanimously.

Robert M. Jenkins, chairman of the Resolutions Committee, presented the following resolutions for consideration.

Resolution No. 1—Establishment of Regional Chairmen as Vice-Presidents of the Society

WHEREAS, the need exists to provide enlarged and expanded services to the membership of the American Fisheries Society such as those derived from the office of an executive secretary; and

WHEREAS, this can only be accomplished by greatly enlarging the membership; and

WHEREAS, it is felt that the most appropriate basic approach at this time is to encourage and strengthen the regions since these subdivisions are closer to more of the members and potential members; and

WHEREAS, this can be done by giving greater recognition, responsibility, and cohesion with the parent body to the regional division:

NOW THEREFORE BE IT RESOLVED, that:

1. The Bylaws of the Society be amended by adding a new Section 25 to read as follows:

"Section 25. The several chairmen of the Regional Divisions, organized pursuant to Sections 21 to 24 inclusive, shall become Regional Vice-Presidents of the Society at the next meeting of the parent society, and shall, in addition to serving as members of the Executive Committee, perform such other duties as may be assigned to them by the president."

2. Further amend the Bylaws by changing the numbers of Sections 25 and 26 respectively to numbers 26 and 27.

3. Then at the 1961 annual meeting amend the Constitution properly to effectuate the above changes, and eliminate the above amendments from the Bylaws.

Mr. Jenkins moved that the resolution be adopted. After a lengthy discussion concern-

ing the constitutionality of the proposed change in bylaws and the operational aspects of the proposed change with reference to membership on the executive committee, Albert Hazzard moved that the motion be tabled. The motion was seconded by Ralph Hile but lost by voice vote. After further debate on the motion concerning the legality of the proposed action, President Moffett declared the motion out of order and therefore the resolution was not adopted in the form presented.

Mr. Jenkins reintroduced the first resolution with the last section amended to read:

NOW THEREFORE BE IT RESOLVED, that:

1. The Bylaws of the Society be amended by adding a new Section 25 to read as follows:

"Section 25. The several chairmen of the Regional Divisions, organized pursuant to Sections 21 to 24 inclusive, shall become Regional Vice-Presidents of the Society and shall, in addition to serving as members of the Executive Committee, perform such other duties as may be assigned to them by the president."

Mr. Jenkins moved adoption of the amended resolution. The motion was seconded by Seth Gordon and passed. [ED. NOTE: This business transpired later in the meeting, but is recorded here for purposes of clarity.]

Resolution No. 2—Regulation of Pesticides Programs

WHEREAS, severe losses of fish, aquatic plants, and other desirable forms of life sometimes follow large-scale applications of chemical poisons in programs participated in by the Federal Government; and

WHEREAS, such large-scale poisoning programs have raised serious questions as to their ultimate effects on the health and safety of mankind itself; and

WHEREAS, little coordination exists among the Federal agencies and State agencies concerned;

NOW THEREFORE BE IT RESOLVED, that the American Fisheries Society urge the Congress to enact a pesticides coordination act that will require the United States Department of Agriculture, or any other department concerned, to confer with the United States Public Health Service and the United States Fish and Wildlife Service, and with the appropriate state agencies in advance of any major proposed pesticidal program; that the control agency's request for the program appropriation be accompanied by a joint report of the several affected agencies, which explains the nature and purpose of the proposed program, the hazards involved and recommends formulations, dosages, times and methods of application of the poisons; and that the affected agencies also be required to have personnel in the field during spraying operations to make such surveys and investigations as are necessary to determine that the public health and fish and wildlife resources are fully protected.

Mr. Jenkins moved the adoption of resolution. It was seconded by Richard Croker. Joseph Barnaby moved that the word "major" before "program" be stricken from the resolution. The motion was seconded by Lyle M. Thorpe and passed. Raymond Johnson moved that the word "spraying" be replaced by "during the period of application." Robert Schumacher seconded the motion, which was passed. President Moffett called for the question and the motion to approve the resolution was passed.

Resolution No. 3—Control of Radioactive Wastes

WHEREAS, the American Fisheries Society advocates the principle that conservation and wise use of natural resources, including all the waters of the earth, are basic to the survival of mankind; and

WHEREAS, the seas, covering 70 percent of the earth's surface, comprise an increasingly important source of food; and

WHEREAS, the seas, when conversion processes have been perfected, will provide a huge supply of fresh water for human uses; and

WHEREAS, the coastal seas of the continent provide a recreational fishing resource of incalculable value; and

WHEREAS, the capacity of the seas to produce these values in perpetuity must seriously deteriorate if subjected to systematic contamination; and

WHEREAS, the seas, in the polar regions, in the deepest valleys of their floors and in the coastal and offshore waters of North America are being suggested as places for continued disposal of radioactive wastes;

NOW THEREFORE BE IT RESOLVED, that the American Fisheries Society urge the Congress of the United States to direct the Atomic Energy Commission, the U. S. Public Health Service and other responsible federal agencies to provide for adequate study and control of all radioactive waste disposal programs by qualified oceanographers and biologists; and

BE IT FURTHER RESOLVED, that all current and future disposal programs be strictly monitored and include continuing studies of the effects of dumping in established sites and that inspectors be assigned to contractors' barges to insure that radioactive wastes are dumped in approved disposal areas.

Mr. Jenkins moved adoption of the resolution. The motion was seconded by John F. and the resolution was adopted.

Resolution No. 4—Federal Assistance Waste Treatment Facilities

WHEREAS, Public Law 660 passed by the 84th Congress in 1956 authorized Federal grants to stimulate the construction of needed municipal sewage treatment facilities; and

WHEREAS, four years of operating experience under this Act has clearly demonstrated the

eral grants have greatly stimulated such construction; and

WHEREAS, studies and surveys by State and Federal agencies clearly indicate the need for an accelerated program of construction to keep pace with burgeoning populations;

NOW THEREFORE BE IT RESOLVED, that the American Fisheries Society urges Congress to enact legislation to increase substantially the actual authorization to assist in the construction of State-approved municipal waste treatment facilities and to strengthen the enforcement provisions of the Federal Water Pollution Control Act to abate pollution of our nation's waters.

Mr. Jenkins moved adoption of the resolution which was seconded by George Bennett. The resolution was adopted.

Resolution No. 5—Establishment of a National Aquarium

WHEREAS, the fresh-water and marine fishes, shellfish, and other aquatic organisms comprise an increasingly important and recognized resource for all the peoples of the world; and

WHEREAS, programs for the conservation, wise use, and management of these resources at the local, state, national and international levels depend ultimately upon having an interested and informed public; and

WHEREAS, the United States has obligations and responsibilities to foster public awareness of interest in these resources and to encourage education of the public concerning them; and

WHEREAS, exhibits of the world's living fishes, shellfish, and other aquatic animals and plants would stimulate the interest of the public and provide a focal point for educational programs;

WHEREAS, the existing national aquarium is inadequate and does not allow appropriate representation of the vast aquatic resources of the world, their importance and contributions to civilization, nor the fundamental interest and concern of the United States in such resources;

WHEREAS, the Nation's Capitol should provide an aquarium worthy of the United States and comparable in every way to such national institutions as the National Gallery of Art, the Library of Congress, and the Smithsonian Institution, which have demonstrated unquestionably their value to all the people; and

WHEREAS, such an aquarium would serve important scientific purposes and essential educational and cultural purposes for the millions of school children and other persons who visit each year;

NOW THEREFORE BE IT RESOLVED, that the American Fisheries Society urge the Congress of the United States to enact legislation to establish, within the District of Columbia, a National Aquarium; and

BE IT FURTHER RESOLVED, that the responsibility for its planning, construction, and operation be vested in the Secretary of the Interior who shall have authority to cooperate with all Federal and State agencies and with other interested parties.

Mr. Jenkins moved the adoption of the resolution. The motion was seconded by Robert Schumacher, and the resolution was adopted.

Resolution No. 6—Funds for Research Programs on High Dams

WHEREAS, many of the remaining economical hydro sites are in the streams which have important runs of anadromous fishes and many of these are high dam sites; and

WHEREAS, fishery research in safe passage and protection of fish at high dams is lagging in comparison to the rate of development of high dams and many of the fish passage and protective facilities being proposed are based upon opinion rather than facts;

NOW THEREFORE BE IT RESOLVED, that the American Fisheries Society does urge the Congress of the United States to provide funds for an accelerated research program to solve the problems of safe fish passage at high dams and that appropriate action be taken by Congress and the governmental regulatory agencies concerned to provide for the orderly development of multiple-use water projects to the benefit of the public welfare.

A motion to adopt the resolution was offered by Mr. Jenkins, seconded by Forrest Hauck, and approved.

Resolution No. 7—Appreciation of Colorado Game and Fish Department

WHEREAS, the American Fisheries Society has, for the fourth time in its history, been the guest of the State of Colorado, and has again enjoyed the warm hospitality of the City of Denver; and

WHEREAS, the many courtesies extended and excellent facilities available have contributed in great measure to the success of this meeting;

NOW THEREFORE BE IT RESOLVED, that our sincere appreciation be extended to the Colorado Game and Fish Department, sportsmen's groups, and many business firms who cooperated in making our 90th meeting an enjoyable and profitable one.

A motion to adopt the resolution was presented by Mr. Jenkins, and seconded and passed by acclaim.

Resolution No. 8—Elimination of Standing Committees

WHEREAS, the continuing expansion of the number of standing committees has contributed to the increase of the Executive Committee (on which chairmen of standing committees are *ex officio* members) to such a level as to make the functioning of that committee inefficient and cumbersome; and

WHEREAS, excessive time is expended at the Society's annual meetings in the presentation of reports of standing committees;

NOW THEREFORE BE IT RESOLVED, that the membership of the Executive Committee be re-

ent was conducted, with Lyle Thorpe, Seaman, John Funk, and I. B. Byrd as tellers. Dr. Edward Schneberger was second vice-president. John Gottschalk moved that the secretary be instructed to cast a unanimous ballot for Edward Schneberger second vice-president. The motion was seconded by Clarence Cottam and approved. Nominations for secretary-treasurer were made. None being heard, Ralph Hile moved that the nominations be closed. The motion was seconded by Kenneth Carlander and approved. John Funk moved that the secretary be instructed to cast a unanimous ballot for Seaman. The motion was seconded by Ralph Hutchinson and passed.

Nomination for members of the finance committee was opened. Seth Gordon moved that the nominations be closed and that the secretary be instructed to cast a unanimous ballot for the nominations proposed by the committee. The motion was seconded by Tom Byrd and approved.

President Moffett thanked the Society for cooperation with him during his term as president and requested that George Holton, A. E. Underhill of New Jersey escort president-elect Carlander to the rostrum. Dr. Underhill accepted the presidency with the following remarks:

"We are going to need the assistance of every member of the Society. With the new arrangement of getting more of the districts, more of the regional men into the Executive Board, giving them a greater part, I think that this is going to be one method of strengthening the Society in the coming year. It is obvious that we are not strong enough to develop financial position so we can hire an executive secretary. The volume of business has just gotten to a point where no man can be expected to voluntarily do the work. Three thousand has been suggested as more or less a magical number that we have to get to. Some people say we need more than that to get or to become financially safe in hiring an executive secretary. This is the day that we are all going to have to get out and get members. The suggestion that was made the other day that we have a special committee to work on ideas for getting members is certainly one that will be followed."

President-elect Carlander then named the standing committees. [ED. NOTE: Appointments were made subsequent to the close of business session.]

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 Bert S. Campbell, Missouri
 Wm DeLacy, Washington

W. Harry Everhart, Maine
 F. E. J. Fry, Ontario
 Shelby D. Gerking, Indiana
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 T. W. Beak, Ontario
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 Terrence P. Frost, New Hampshire
 Forrest R. Hauck, Idaho
 William H. Irwin, Oklahoma
 Max Katz, Washington
 Eugene W. Surber, Georgia
 William M. Van Horn, Wisconsin

Committee on Names of Fishes

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 Ernest A. Lachner, Washington, D. C.
 C. C. Lindsey, British Columbia
 C. Richard Robins, Florida
 Phil M. Roedel, California
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 John Greenbank, Colorado
 James Mullan, Massachusetts

Committee on Society Organization

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 Keen Buss, Pennsylvania
 Lauren R. Donaldson, Washington
 Justin Leonard, Michigan
 Gustav Prevost, Quebec

Committee on Executive Secretary

John Funk, Missouri, Chairman
 Tom Dolan, Pennsylvania
 Louis Krumholz, Kentucky
 Edward Schneberger, Wisconsin
 Al Swartz, Washington, D. C.

Awards Committee

William F. Sigler, Utah, Chairman

Nominating Committee

Fred Thompson, New Mexico, Chairman
 John Budd, Ontario
 C. J. Campbell, Jr., Oregon
 Robert G. Martin, Virginia
 Britton McCabe, Massachusetts
 Robert Sharp, Minnesota
 Paul Thompson, Washington, D. C.

AIBS Program Committee

Shelby D. Gerking, Indiana, Chairman
 H. T. Odum, Texas
 D. S. Rawson, Saskatchewan

*Committee on Liaison with
Trout Breeders' Association*

Wayne Seaman, Colorado, Chairman

*Committee on Coordination of
National-State Programs*

William R. Beckman, Massachusetts,
 Northeastern Division
 Melvin T. Hursh, Florida, Southern Division
 Alphonse Kemmerich, Oregon, Western Division
 Jerome Kuehn, Minnesota,
 North-Central Division

*Committee on Methods of
Membership Promotion*

George Eicher, Oregon, Chairman
 Richard Croker, California
 Paul Eschmeyer, Michigan
 Robert Jenkins, Washington, D. C.
 Clarence Pautzke, Alaska

Membership Committee

Richard Croker, California, Chairman
 Charles R. Curry, California
 William A. Dill, Italy
 Gordon E. Hall, Tennessee
 George D. Holton, Montana

Edward S. Marvich, Alaska
 H. J. McKirdy, Alaska
 Robert G. McMynn, British Columbia
 Edward Schneberger, Wisconsin
 Roland F. Smith, New Jersey
 Hjalmar Swenson, Minnesota
 John Van Oosten, Michigan

The President asked for new business. D. Riggs, who represented the American Fisheries Society at the AIBS meetings, made following report:

Past-President Moffett asked me to represent the Society at the annual meeting of AIBS Stillwater, Oklahoma, during the past month and I did this. To me one of the most important things that came up in this meeting was the urging of the Executive Committee of AIBS that the affiliated associations to try to make closer ties to AIBS. Now, those of us who have attended AIBS meetings regularly are aware that we see many members of this association, of this Society, that we do not see at the Society meetings. We also see some past members of this Society. We can't explain why they are no longer members. Maybe it is because they do not have opportunity to attend our meetings as much as they should.

I think it would be very wise for this Society to have a meeting room at AIBS meetings, and I also think it would be very worthwhile if the Society had a program meeting at the AIBS. In other words, this would either be by ourselves or possibly in conjunction with the American Society of Limnology and Oceanography, if we did not have enough papers for a program. This would mean that members who attend AIBS and who are unable to attend this meeting (there were some 20 papers presented to this meeting) would be able to give these. They would be in the program, and the Society would certainly receive more recognition by some of the academic people than we are getting. At the close of the Executive Committee meeting there, where I was very warmly welcomed, three or four of the AIBS Executive Committee said, "What is this association that you represent here?"

Dr. Riggs moved that a program meeting of the Fisheries Society be established at the next meeting of AIBS in 1961. Karl Lauder seconded the motion, which was passed.

After making closing announcements, the President asked for a motion to adjourn. This was made by Marion Toole, seconded by Clarence Pautzke, and passed. The meeting was adjourned at 5:10 p.m.

REPORTS OF OFFICERS AND COMMITTEES

Report of Secretary-Treasurer

E. A. SEAMAN

For a somewhat rough and tumble year of transition at times my saneness to present annual report. When finances brought more worries than usual in June of this year I blew my top at the President and berated the Editor. It is annoying to get berated here and there on correspondence which tell you, or intimate, that you are a nut. A little nasty profanity splashed in by some doesn't help either. (I wish I were clear here, since I just mentioned my relations with the President and Editor, I'm referring to these gentlemen or any of the Executive Committee!) One member, in commenting on the *Newsletter*, said I should read *Ernest Nagel's Make Your Technical Writing Useful* (which we sell, as you know) and make my writing more useful! My only excuse is that my writing in the *Newsletter* isn't always useful and certainly it is not "technical."

We have said your Secretary-Treasurer is too progressive. One member demanded "retrench!" May I ask, retrench from what? My limitations are determined by what our membership wants, and of course specified by what the Executive Committee decides. I could be remiss if I did not state that the workload of this job is heavier than it was last year. Correspondence of the Society has increased phenomenally. We often receive four or more questionnaires per month, for instance. These come from organizations such as the National Science Foundation, the American Institute of Biological Sciences, independent survey polling groups, and so forth. It takes time to oblige in reply, yet the time is spent because it is essential that scientific societies cooperate in this regard. Collecting dues from slow-paying members was the greatest single burden in the past fiscal year. The Society is not alone in this problem, for it is common to all types of societies. Our Secretary-Treasurer welcomes new ideas and tries to get members to be prompt in meeting this obligation.

At the close of the fiscal year we suffered from less than expected revenue because 189 were delinquent from the rolls because they were 2 months in arrears. This meant a loss of about \$100.00. As of August 31, 1960, we had outstanding the sum of \$3,950.00 due to those

late in paying current and last fiscal year dues. This represents 680 out of 2,073 total membership failing to meet the responsibility of paying their dues.

A change to calendar-year billing of dues was instituted. Half-year dues were charged active members July 1, 1960. Full annual dues will be billed the entire membership November 5, 1960, for the next calendar year of 1961.

In speaking of dues, it is interesting to note that the Society's dues were \$3.00 in 1870; \$5.00 in 1872! To those who complain about what they get for \$10 in the year 1960 . . . all I can say is that with inflation coupled with an excellent quarterly journal, a newsletter, various services added, and the like, our members are doing well these days. We have come a long way from being organized in a New York City skating rink to meeting here in this luxurious new hotel 90 years later.

One significant source of income during the fiscal year was the receipt of \$4,775.00 from the National Science Foundation for publishing Special Publication Number 2. Without this aid the Society would be in bad financial straits at this date.

The Society's books were audited this year by Howard C. Haire, Public Accountant, Washington, D. C. His report and financial statement show our records to be in order. These reports are in the hands of the Audit Committee, and official presentation will be given in the quarterly *Transactions*.

Our cash balance as of July 1, 1959, was \$10,360.42. Receipts for the fiscal year of 1959-60 consisting of annual dues, dividends, and sale of publications, totaled \$30,047.20; \$4,775.00 of this amount was the National Science Foundation grant.

Disbursements totaled \$32,071.17, the greater part of which involved, as usual, printing costs. As of June 30, 1960, the cash balance was \$8,344.04. The lower than expected cash balance is due to billing only half-year dues in June, 1960.

Income from sale of publications will increase hereafter since we now handle two new fast-selling publications, Special Publication No. 2 (*A List of Common and Scientific Names of Fishes from the United States and Canada*) and *Make Your Technical Writing Useful*. The latter was published jointly with The Wildlife Society, originally financed

by the American Conservation Association. Handling sales of these two publications in conjunction with the quarterly is proving to be a big job. The amount of billing and correspondence, as well as bookkeeping, has increased tremendously. All sales proceeds, less handling costs, received in the sale of Special Publication No. 2 will be returned to the National Science Foundation for a period of 3 years.

The total assets of the Society as of June 30, 1960, were \$19,659.56. This includes cash on hand, U. S. Government bonds (value of \$8,211.50), Mutual Fund stock (valued at \$2,226.50), and fixed assets in the form of office equipment at \$950.72.

Upon the recommendation of the Finance Committee, Chairman Seth Gordon, and approval of the Executive Committee, the Secretary-Treasurer sold our corporate stock and bought 146 shares in the Massachusetts Investors Trust Company of Boston. Dividends obtained are now being reinvested into added shares. For further details on the financial status of the Society full accounting herewith follows:

AMERICAN FISHERIES SOCIETY

FINANCIAL REPORT

FOR THE FISCAL YEAR

JULY 1, 1959, TO JUNE 30, 1960

Cash balance as of July 1, 1959 \$10,360.42

Receipts:

Membership dues:	
a. Active	\$16,268.00
b. Student	1,075.00
c. Foreign	389.75
d. Military	40.00
e. Official	1,960.00
f. Library	1,699.75
g. Sustaining	450.00
h. Life	175.00

Other:

Sale of Transactions and Special Publications	2,749.45
Dividends, stock	74.20
Miscellaneous	458.55
National Science Foundation grant	4,775.00

Total receipts \$30,114.70
Less returned checks 67.50

Total \$40,407.62

Disbursements:

Printing expense	\$20,569.05
Postage and office expense	1,473.49
Meeting expense	400.00
Reporting service	305.19
Audit service	150.00
Fidelity bond	62.50
Insurance	100.83
Safe deposit box rental	5.50
Editor's stipend and expenses	2,495.00
Secretary's stipend and expenses	1,165.56
Contributions	200.00
Awards	50.00
Secretarial service	3,151.90

Warehouse storage	229.77
Shipping library expenses	1,209.51
Special Publication cost	200.00
Telephone and telegrams	20.80
Miscellaneous	126.94
Freight expense	55.13
Advertising	50.00
Dues	50.00

Total disbursements \$32,071.19

Balance \$ 8,336.47

Petty cash credit balance 7

Cash balance as of June 30, 1960 \$ 8,344.04

ASSETS

Current assets:

Cash—bank	\$ 8,344.04
Petty cash	21

Securities:

U. S. Government bonds	8,211.50
Mutual Fund stock	2,226.50

Fixed assets:

Office equipment	\$ 950.72
Allowance for depreciation	855.00

Total assets \$19,659.56

UNAPPROPRIATED SURPLUS

Unappropriated surplus \$19,659.56

SECURITIES

1. U. S. Government savings bonds:

Certificate number	Date issued	Cost	Maturity value
D682395F	8/29/49	\$ 370.00	\$ 500.00
D702345F	12/21/50	370.00	500.00
M1703542F	12/21/50	740.00	1,000.00
M18441J	10/20/52	720.00	1,000.00
M18346J	10/20/52	720.00	1,000.00
M18347J	10/20/52	720.00	1,000.00
M18348J	10/20/52	720.00	1,000.00
M18349J	10/20/52	720.00	1,000.00
M18350J	10/20/52	720.00	1,000.00
M18351J	10/20/52	720.00	1,000.00
M18352J	10/20/52	720.00	1,000.00

Total \$7,240.00 \$10,000.00

2. Mutual Fund stock:

Massachusetts Investors Trust of Boston

Date purchased	Shares	Cost per share	Total cost
August 25, 1959	146	\$ 15.25	\$ 2,226.50

The Secretary has prepared and mailed five issues of the *Newsletter* since the last annual meeting. One poll was conducted with the membership, namely the questionnaire to the Committee on Professional Standards. Chairman, Dr. Lloyd Smith. The brochure *Fisheries As A Profession* continued to be in demand for schools and career guidance groups. A second printing this year of 5,000 is nearly exhausted. A list of members of the Society was prepared and made available upon request. The Constitution and Bylaws was printed this year as a separate leaflet. Both of the above printings were made outside the quarterly to conserve space for papers.

The Secretary-Treasurer represented the Society at the 7th National Watershed Congress in Washington. The Society is a participating member. We maintained our affiliate me

ship in the American Institute of Biological Sciences, as well as the National Resources Council of America.

To consolidate facilities further and promote more economical and more efficient operation of Society business, the stock of publications was moved from Ft. Collins, Colorado to Washington, D. C. It is stored with most through the courtesy of a national library agency. The expense of moving the library amounted to \$1,439.28. Government bonds to the amount of \$2,235.00 were sold at the end of the fiscal year to cover expenditure of moving the library, as well as heavy quarterly printing bills. This accounting is not reflected in the fiscal year statement because redemption of the bonds occurred after July 1, 1960. It is to be noted that the auditor of our books this year recommends in the Society report the inventory of our publications on hand as an asset of the Society. The Secretary-Treasurer is of the opinion that this recommendation should be accepted.

The August 1960 *Newsletter* stated that all members would receive, as in the two previous years, a copy of the printed program of the meeting. Copies were not supplied by the local committee. Your Secretary regrets this disappointment.

During the year the Secretary-Treasurer submitted a request for tax exemption to the Internal Revenue Service. At this date no action has been taken on our request.

Report of Committee on Professional Standards for Fishery Biologists

LLOYD L. SMITH, JR.

After presentation of the report on professional standards at the 89th annual meeting of the American Fisheries Society, the committee was reappointed and charged with the task of determining the reaction of the membership at large to the problems of professional standards raised by the report, and to present further recommendations. To this end a questionnaire prepared by the committee was circulated to the entire membership. It included 10 questions which appear to be directed to a rational approach to the problem of professional standards by the Society. Of the total number of questionnaires sent out representing approximately half the ac-

tive individual membership, were returned. In the entire group, 720 were considered to represent the opinion of practicing biologists. These biologists probably include about three-quarters of the biologists in the membership. The committee believes that it is to be inferred that the majority of those who did not reply to the questionnaire are indifferent to the problem of professional standards and that any action with reference to standards would be of small concern to them or possibly would result in their dropping membership. It seems obligatory, therefore, that we consider that those who have answered constitute most of the members who have definite opinions on this subject.

The segregation of respondents into biologists and nonbiologists was made on the following basis. Those whose payroll title specified that they were biologists or those who indicated that a substantial portion of their work was in research or application of biological principles to management problems were classified as biologists. All others were classified as nonbiologists. A number of those classified as nonbiologists indicated that their training and background would qualify them for a biologists classification on the basis of minimum requirements outlined in the previous report.

Questions 1-5.—Questions 1 through 5 relate to title, employing agency, and sectional location. Answers to them permitted segregation of responses into various regional and occupational groups.

Question 6: Approval of committee definition of fishery biologist.—In its last report the committee defined a fishery biologist as "a professionally trained person capable of defining and investigating problems related to fisheries, and of proposing scientifically sound solutions of the biological problems in sport and commercial fisheries. The fishery biologist can be expected to have a working knowledge of basic biology, chemistry, physics and mathematics as applied to aquatic problems and a specialized knowledge of aquatic biology and fisheries. He must also be capable of presenting results and recommendations in suitable written and oral form."

The members were asked to state acceptance or rejection of this definition. Eighty-nine and seven tenths percent of all respondents and 91.4 percent of the biologists agreed with the definition of a fishery biologist as presented above (Table 1). It is concluded, therefore, that this definition is generally ac-

TABLE 1.—*Answers to questions 6, 8, 9a, and 10 of questionnaire on professional standards*
[875 reporting—(720) biologists]

Number in each group	Percentage answering each question ¹							
	Number 6		Number 8		Number 9a		Number 10	
	Yes	No	Yes	No	Yes	No	Yes	No
Academic 158 (158)	88.6 (88.6)	7.0 (7.0)	85.4 (85.4)	11.4 (11.4)	39.2 (39.2)	57.0 (57.0)	36.7 (36.7)	5 (5)
Federal 232 (196)	90.5 (90.8)	7.3 (7.7)	83.2 (87.2)	13.4 (9.2)	46.6 (50.5)	51.7 (48.0)	33.2 (32.7)	6 (6)
State 352 (284)	93.5 (94.0)	3.4 (3.9)	82.1 (87.3)	12.8 (7.7)	67.0 (73.2)	29.0 (23.6)	42.9 (43.7)	5 (5)
Other 133 (82)	79.7 (89.0)	6.8 (7.3)	59.4 (86.6)	30.1 (9.8)	38.3 (53.7)	42.9 (39.0)	32.3 (45.1)	5 (5)
Total 875 (720)	89.7 (91.4)	5.6 (6.0)	79.5 (86.8)	15.3 (9.2)	52.2 (57.4)	42.2 (39.3)	37.6 (39.3)	5 (5)

¹ Differences between sum of "yes" and "no" and total number of respondents (or 100 percent) represent answers not specified.

ceptable as a basis for further work on problems of standards. Of the approximately 6 percent who disagreed with the definition, most based their criticism (Question 7) on the fact that a number of specializations such as biochemistry, physics, statistics, and bacteriology are an integral part of fishery research and that any definition which excludes specialists in these fields from the group of fishery scientists would be unrealistic and undesirable. Other minor differences were based on the lack of consideration of the sociopolitical involvements with which a fishery biologist must cope in his daily work.

The question of noninclusion of needed specialists in other fields would seem to be most easily resolved by calling them by their respective titles (chemist, physicist, statistician, *et cetera*) and using separate standards based on those already acceptable in these professions. Any attempt to include these specialists in a broad definition of fishery biologist will make such a definition so loose that any meaningful consideration of standards would be extremely difficult if not impossible. Consultation with a number of specialists who are not trained aquatic biologists but who are participating in some phase of fishery investigation or management indicates that they are quite well satisfied to be designated by their specialization and in most cases regret the necessity of being submerged in some general term for the convenience of personnel classification in the various agencies.

Question 8: Would you qualify as biologist under tentative classification already proposed in previous report.—Of all the respondents

to the questionnaire, 79.5 percent indicated that they could qualify under the specializations set forth in the previous report to the committee as minimum requirements for fishery biologists. Eighty-six and eight tenths percent of those classified as biologists stated that they would qualify. There was little variation in the percentage which qualified in various employing agencies. It is to be assumed from these returns that minimum specializations based on the background training tentatively outlined in the previous report would incorporate all but a small minority of practicing fishery biologists in the Society, unless it is assumed that the biologists not replying are, for the most part, unqualified for work they are doing.

Question 9a: Do you at present feel lack of professional standards is a disadvantage to you.—In answering the question concerning the effect of lack of defined professional standards on members of the American Fisheries Society, 52.2 percent of all respondents and 57.4 percent of biologists felt that this deficiency was a definite detriment to them. If it can be assumed that those individuals not replying to the questionnaire are different to the problem of standards, or slightly more than a quarter of the present membership of the Society feels that establishment of professional standards would be advantageous to them. It should be pointed out, however, that many of those who indicated that lack of standards was a detriment were quite vehement in their expression and documented their stand.

2.—Reasons why lack of standards was felt a disadvantage

157 "yes" answers to question 9a; (413) biologists]

in group	Percentage answering each item of question 9b				
	1	2	3	4	5
	72.6 (72.6)	11.3 (11.3)	16.1 (16.1)	51.6 (51.6)	25.8 (25.8)
	77.8 (80.8)	3.7 (4.0)	13.0 (13.1)	50.0 (48.5)	27.8 (29.3)
	91.5 (95.7)	7.2 (7.2)	20.8 (20.7)	50.4 (51.9)	22.5 (23.1)
	76.5 (79.5)	15.7 (15.9)	25.5 (25.0)	51.0 (56.8)	43.1 (43.2)
	84.0 (86.9)	7.9 (8.0)	18.8 (18.6)	50.5 (51.6)	26.5 (27.1)

Question 9b: *Reasons for professional standards.*—Five general reasons for the lack of standards was a disadvantage specified. They were: (1) salary, (2) tenure, (3) inability to perform professional duties satisfactorily, (4) lack of prestige, and (5) others.

The 457 respondents who stated that they lack of professional standards was a disadvantage to them, a majority (84 percent total, 86.9 percent of biologists) believed that salary status was the principal cause for dissatisfaction (Table 2). The second largest cause of complaint (50.5 percent total, 51.6 percent of biologists) was personal prestige. Twenty-six and four percent of all respondents listing dissatisfaction had a variety of other reasons for their position. The most significant were difficulty in recruiting adequate personnel, lack of recognition, and difficulty in getting credit for management recommendations and the importance of biological work in fisheries.

Relationship of age group to questions of professional standards.—A break-down of the responses by successive 5-year groups based on number of years the respondent has been employed in fisheries work (Table 3) showed that in general, men with less than 5 years' experience were more poorly qualified on the basis of background training than men who had been in fisheries work 6 years or more. This is a disquieting commentary on the quality of new recruits to the field. As would be expected, a much larger proportion of the respondents serving less than 10 years felt the lack of standards than those who have been in serv-

TABLE 3.—Answers to questions 8, 9a, and 10 given by biologists and segregated by years of service¹—expressed as percentage

Question	Years of service					
	0-5	6-10	11-15	16-20	21-25	Over 25
Number 8						
Yes	83.7	92.2	91.6	82.5	94.2	87.2
No	11.6	5.9	7.6	14.0	2.9	8.5
Not specified	4.7	1.1	0.8	3.5	2.9	4.3
Number 9a						
Yes	66.9	66.3	61.3	45.6	38.2	25.5
No	32.6	32.2	36.1	52.6	58.9	70.2
Not specified	0.5	1.5	2.6	1.8	2.9	4.3
Number 10						
Yes	43.8	42.4	39.5	33.3	35.3	17.0
No	54.9	56.1	58.8	64.9	61.8	80.8
Not specified	1.3	1.5	1.7	1.8	2.9	2.2
Total number in each group	233	205	119	57	34	47

¹ Answers of 25 who did not specify length of service are not included.

ice longer than 10 years. Only about one-quarter of the men who had 25 years or more in fishery work felt any lack of standards.

Regional variations in answers.—Answers to the questionnaire were tabulated separately by regions to determine whether or not any significant differences in opinion existed on a geographical basis. With particular reference to question 9a concerning the need for professional standards, the Western Division with 60.8 percent felt that lack of standards was a disadvantage to them. Lack of standards was felt to be least important in the Northeast where 43.2 percent reported that this deficiency was detrimental to them. The Southeast and the North-Central regions were similar in their responses, with slightly more than 50 percent of the respondents feeling the lack of professional standards. In answers to other questions no clear-cut regional pattern was developed.

Question 10: Use of professional standards as qualification for membership in the American Fisheries Society.—Of all respondents 37.6 percent, and of biologists, 39.3 percent, felt that membership in the American Fisheries Society should be related to attainment of minimum professional qualifications. It therefore appears that the majority sentiment is not in favor of making the Society a strictly professional group at this time. When this question was evaluated on the basis of age groups, a slightly higher proportion of the respondents with less than 10 years of service favored a professional society. As length of

time in service advanced there was a marked decrease in the number of people who felt that professional standards should be related to Society membership.

RECOMMENDATIONS

In appraising results of this questionnaire it is evident that the American Fisheries Society as a whole is not yet ready to go into an elaborate program of accreditation of biologists on the basis of minimum standards for the practice of biological work in fisheries. It is also apparent, however, that a significant segment of the Society feels such needs very acutely. It was suggested by many who answered the questionnaire that a professional group be set up within the Society to take care of the needs of biologists and that professional standards be used as a criterion for inclusion in the group. Important as the needs for professionalism among fishery biologists are, the Society might well founder on ill advised or premature attempts to establish a strictly professional Society. It is essential, therefore, that the Society proceed with caution in the development of a program designed to improve the status of biologist members.

It is evident that in many areas no clear-cut criteria exist in the employing agencies for the selection of fishery biologists. There is also no minimum standard or, in a few cases, no clear understanding among educational institutions of background training required to produce a competent fishery biologist. In view of these considerations and in light of the opinions expressed in the questionnaire, the Committee submits the following recommendations:

- 1) A set of minimum requirements for background training leading to acceptable competence in the field of fishery biology be formulated as a suggested guide for educational programs and for employment procedures in various agencies.

- 2) No attempt should be made to establish background requirements or to set standards for fishery scientists who are specialists in chemistry, physics, statistics, or allied fields, but such qualification in the future should be based on standards already acceptable in these fields.

- 3) Accreditation of biologists by the Society should not be attempted until general acceptance, both by educational institutions and employing agencies, of the minimum requirements approved by the Society is attained, and until the structure of the Society

is such that an accreditation procedure can be made effective and kept current.

- 4) Professional standards should not be used as a basis for membership in the American Fisheries Society.

- 5) The Society should cooperate with other groups now considering the problems of professional standards for fishery biologists.

Report of Editorial Board

LLOYD L. SMITH, JR.

During the past year the task of the editorial board has been to produce issues on time and to consolidate the position of the quarterly *Transactions* as a periodical fisheries journal. During the year 117 manuscripts, totaling 2896 pages, have been considered. Fifty-six papers have been printed; 17 manuscripts have been rejected; 29 are on the editor's desk scheduled for appearance in future issues; and 45 are in the authors' hands for revision. The large editorial task has been accomplished by the regular editorial board of 11 members and 9 additional specialists in particular fields.

High costs of publication have plagued the Society as they do all societies publishing scientific material. The Conference of Biological Editors estimates an average cost of 6¢ per word. This is approximately the cost of volume 89 of the *Transactions*. Fortunately we have succeeded in obtaining a very favorable printing arrangement which will reduce costs and permit the publishing of more papers in future volumes.

We are now a member of the Conference of Biological Editors and are actively cooperating with *Biological Abstracts*.

One major problem is the printing of papers that have merit but cannot be carried in the quarterly without unfair elimination of shorter papers. To help meet this problem the Editorial Board recommends that the Editors be authorized to accept longer papers for inclusion in the *Transactions* and to charge authors or their organizations on a cost page basis for all pages exceeding 15 printed pages, but that papers longer than 40 printed pages will not be accepted. The Board further recommends that it be authorized to seek accept outside sponsorship for meritorious long papers that cannot be supported financially by the author or his organization.

As the quarterly completes its second volume, the quality of papers is improving

of papers is all we can handle, and the Editorial Board is looking forward to the maintenance of a journal which will continue the credit to the Society.

Report of Committee on Names of Fishes

REEVE M. BAILEY

In the nature of the work of this Committee that effort be concentrated periodically in the preparation of a list of names of fishes. In the publication of Special Publication No. 2 in 1958, the activities of the Committee are conducted at a reduced level until active work commences for a third edition of the list of common and scientific names. During the interim between appearance of the first and second editions some changes were recommended in the annual reports of this Committee in the *Transactions*. It is the consensus of the Committee, however, that this procedure is unsatisfactory and we do not plan to make changes until a third list is prepared. The list of names of fishes should be subjected to periodic revision. Changes in knowledge of the dynamic dispersal of species necessitate modification. For example, during the past 5 years several fishes made their initial entry from Mexico into United States waters of the warming eastern Pacific. Not only common names selected for this list will likely prove acceptable, and it is in the selection of scientific names that they change to reflect current knowledge of classification and relationships. In view of the need for additions and changes it is anticipated that the list of names should be modernized and reprinted probably at intervals of approximately 5 years.

The files of the Committee on Names of Fishes remain active. Since appearance of Special Publication No. 2 several comments and suggestions for improvement of the list have been received and we welcome further suggestions. As deficiencies in the list are noted we urge that they be communicated to the Committee for consideration prior to publication. The Committee takes this opportunity to express its sincere thanks to the many members of the Society who have contributed helpfully and constructively to its work.

Report of Committee on National-State Relations

EDWARD H. SCHNEBERGER

The bylaws of this Society define the National-State Relations Committee as a coordinating and advisory board for the consideration of interstate and national-state fishery problems and programs. The Committee is further instructed to consider problems of administration of the fishery resources, federal and state legislation, and the implementation thereof in the field of fishery conservation and management. The Committee for 1958 and 1959 directed its efforts toward the solution of problems causing conflict and strain between the federal and state agencies. The report for 1959 showed excellent progress was made, and therefore further exploration of this subject seemed unnecessary.

The present committee felt it would be profitable to explore the roles of both federal and state agencies in the fields of research and management. Coordination of activities to avoid duplication of effort is certainly desirable. The ideal goal is one that will direct the activities of the federal agencies toward problems which the states are unable to handle. In most areas of the nation, fish culture on a production basis is one of these fields. Basic problems associated with fish culture, however, such as research in nutrition and disease control and prevention, are fundamental problems to which the federal agencies can contribute a great deal. The development of farm fish ponds has grown tremendously during the past decade and presents a variety of problems across the nation. Some states are unable to devote much effort to this program because they lack funds and manpower; and in some states the law prohibits state participation unless the public is allowed fishing rights and privileges. In such instances the role of the federal agency is quite clear and important.

The role of the federal agency can be placed in the following categories: (1) long-range basic and fundamental research; (2) interstate fisheries including boundary waters, anadromous fish, and large reservoir problems; (3) commercial and sport fishing relationships in both the Great Lakes and coastal waters; (4) international fisheries; and (5) fee title to lands.

LONG-RANGE FUNDAMENTAL RESEARCH

Most states for a variety of reasons have difficulty maintaining a basic long-range re-

search program. Lack of funds is perhaps the most important deterrent; however, other factors are changing administrations and inability to pay adequate salaries to hold talented researchers. There are, of course, a great many fishery problems upon which basic and fundamental research is needed. A complete listing is not attempted at this time, and only a few are mentioned to stress this point. Research on fish diseases and nutrition has already been cited. Although considerable work has been done in this field, much remains to be accomplished. Such research should be greatly expanded in the area of fish physiology, blood chemistry, and so on.

The role of chemicals as toxicants and of electricity in modern fish management is becoming increasingly important. The use of such materials as rotenone and toxaphene in eradication of undesirable species and the subsequent rehabilitation of such waters is well known to all. There is a need for toxicants that are specific for individual species at a reasonable cost. The ability to remove or reduce one or more undesirable species in a body of water without destruction of the entire population would mark a great advance in fish management. The feasibility of this procedure has already been demonstrated in the search for a selective toxicant to control the sea lamprey in the Great Lakes. The U. S. Fish and Wildlife Service at the request of several midwest states has established a laboratory at LaCrosse, Wisconsin, for further exploration of these problems. This activity should be expanded as rapidly as possible.

Closely related to the above need is a need for much more information on the tolerance of fishes to various chemicals. The recent rapid growth of pesticides and herbicides and similar products has emphasized the need for knowledge on the effect of these chemicals on fish and other wildlife. The Fish and Wildlife Service laboratory at Denver is already engaged in this work, but such activities need to be expanded greatly to keep up with the very rapid development of new pesticides.

It is not necessary to stress the need and value of research. There is need, however, to consider the administration and supervision of research. In the recent trend to develop and improve efficiency in office management or administration, there is a tendency to organize research units on the same basis as production or service divisions with a strict cataloging of the individual's time and measurement of the researcher's worth on a cost-

accounting basis. Research should be created and the researcher should be equipped with imagination which he is given freedom to exercise. Discovery of new knowledge cannot be directed or prescribed. We do not imply that researchers are not to be supervised or to be absolved from all accountability, rather that organizations do not get so involved in the zeal of efficient administration that the effectiveness of the researcher is negated by administrative rules of red tape. At the same time care must be taken not to put research in the so-called "ivory towers." Instead research should work closely with production and service units of the organization. It is not the purpose of this report to discuss organization charts, procedures, methods, but rather to emphasize the need for liaison between research, production, and administration. Without good liaison, research cannot know the problems, and operating or service units have difficulty in translating the results of research into operating procedures.

INTERSTATE FISHERIES

This category contains many problems that can be solved only through cooperative effort among the several states and federal agencies. In many of the nation's large rivers that serve as the boundary between two or more states it is not uncommon to find an entirely different set of regulations governing the taking and harvesting of fish from areas separated only by an imaginary boundary line. Uniformity of regulations along with uniformity of management procedures is essential. In some areas no effort has been made to achieve uniformity of either; however, in other areas considerable progress has been made through cooperative efforts of those concerned. In the upper Mississippi River, for example, Wisconsin, Minnesota, Iowa, Illinois, and Missouri have been working jointly on problems of the Mississippi River for more than 15 years. Although considerable progress has been made, there are handicaps that prevent the full utilization of the various states' resources in the solution of the problems. The inability of survey crews to cross state lines and work on non-navigable waters is perhaps the greatest handicap. However, the U. S. Bureau of Sport Fisheries and Wildlife has been an *ex officio* member of the Upper Mississippi River Conservation Committee and recently has provided the services of an employee to coordinate state efforts in this program. In this instance we see

ple of several states attempting to do research and to solve management problems for themselves with the federal agency extending coordination and direction in those phases of the program with which the states are unable to cope. This cooperation has been extremely valuable.

The Northwest states bordering the Columbia River, through recent organization, have been able to incorporate a research institution in which the state agencies will exercise coordinating and operating control. Consequently, the incorporated body they can contract with and agree to do research, whether basic or applied. This organization has been able to develop flexibility that can overcome the handicaps of legal and fiscal rules which frequently hamper the activities of state agencies.

With the development of reservoirs on many of the larger rivers by the construction of dams for hydro-electric power, irrigation, and other purposes, a problem of proper management of fishes in these waters has come into existence. Usually these problems are too large for a single state to undertake, or when a reservoir borders on two or more states, interstate problems are created. This seems to be another example where the federal agency can take over to an advantage.

COMMERCIAL AND SPORT FISHING RELATIONSHIPS

The problem of commercial and sport fishing in both the Great Lakes and coastal waters is similar to that discussed above; however, the problems are complicated to a greater degree by the conflict of sport and commercial fishing interests. There are some who believe the entire fishery should be reserved for the sportsmen, while others take the opposite view. In many instances there are species of fish present that are of no interest to the sportsmen. Consequently, the commercial fisherman plays a very important role in harvesting the unused fish as food and adding to the general economy of the region as well as to the nation. Methods of management must be developed to permit harvest of available populations in such a manner that conflict between commercial and sport fishermen is avoided. In the Great Lakes the invasion of the sea by alewives and the subsequent destruction of lake trout and whitefish precipitated the development of an international treaty with Canada for the control of the lamprey and the conduct of research on the management of fishery resources. The Great Lakes Fish-

ery Commission has been in existence only a few years, but has been successful in coordinating the efforts of two national governments, the province of Ontario, and the several states to bring about results which have created considerable optimism about a solution of the problem. In the activities of this Commission the research talent of the federal agencies is contracted and a well-balanced program has been developed and placed into operation. The program incorporates the talents and resources of the several states and the province so that all are working toward a common goal without duplication of effort. Similar treaties on the important fishery of the coastal waters have been in operation for a number of years. The success of such organizations has been outstanding but need not be listed here.

INTERNATIONAL FISHERIES

The international fishery of the oceans is a problem of principal concern to the federal agencies. Here again various treaties have been enacted and have developed research and management programs which have proved successful. This field is one that is without question entirely in the field of the federal agencies.

FEE TITLE TO LANDS

Federal leadership should be provided in maintaining free public access to waters, either natural or impounded, that are under control of federal agencies. This is particularly true of the large impounded waters created by the Bureau of Reclamation or the Army Corps of Engineers, and should include the acquisition of proper amounts of peripheral lands that need be held for public purposes. The Federal Government has an obligation to enhance the recreational facilities of such areas to the extent of its abilities, consistent with the primary purpose of the areas involved.

RECOMMENDATIONS

1. It is recommended that the federal agencies be the leaders of long-range fundamental and basic research programs. It is believed that the federal agencies are best equipped to carry on such a program and can insure the continuity of the programs much better than the states.

2. It is recommended that serious efforts be made to discontinue or minimize duplication of services and efforts wherever possible.

3. It is recommended that the federal agen-

cies acquire fee simple titles to reasonable amounts of peripheral lands around reservoirs.

The Committee recognizes that such a program cannot be accomplished without considerable effort and study. It is believed that the logical approach to such a program by the Society is through each of the regional divisions of the Society working with the regional offices of the U. S. Fish and Wildlife Service. It is therefore recommended that the parent Society instruct the regional officers to inaugurate such a program for each of the divisions wherein the problems of duplication can be studied and means for elimination developed. The several divisions of the Society working with the regional offices of the federal services can also develop long-range research programs in keeping with the needs and conditions of the various regions so that information can be obtained on problems of the particular region.

Report of Committee on International Relations

WILLIAM A. DILL¹

For many years the work of the Committee on International Relations has been almost entirely confined to the presentation of an annual report. The scope and length of the report have varied decidedly from year to year, and it would appear that each Committee has been in somewhat of a quandary as to what type to present. Several previous chairmen have stated that the task of the Committee (as defined in the bylaws of the Society) has become more and more difficult and have prophesied that "... in the not-too-distant future will be almost impossible."

The present Committee wishes to go beyond these conservative opinions and say that it is impossible. The world of fisheries is now too large and international activities are too numerous for a small and impermanent committee to treat them with any degree of completeness. This year's report is prepared, therefore, with no pretense of completeness or rigid order. We have erected a rough framework and then described a few significant events as illustrative of the wide-ranging series of accomplishments, promises, and trends in the world of international fisheries.

¹ Present address: Biology Branch, Fisheries Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

MEETINGS

Undoubtedly, the meeting exciting the greatest attention was the Second United Nations Conference on the Law of the Sea attended by 88 nations, at Geneva in the spring of 1960. None of the proposals gained the necessary two-thirds majority, and the Conference ended without having arrived at agreement on a rule of law on the territorial sea and fishing limits.

Also of world-wide interest, and held to date for inclusion in the report of last year's Committee, was the First International Oceanographical Congress at New York (August-September 1959). Since then there have been many other meetings in the various fields of oceanography, culminating in the Intergovernmental Conference on Oceanographic Research, at Copenhagen, July 1960. The Conference recommended the establishment of an Intergovernmental Oceanographic Commission (IOC) to be a body within the framework of the United Nations Educational, Scientific and Cultural Organization (UNESCO) with the aim of promoting the science of oceanography in all its branches: biology, chemistry, geology, and physics. The General Conference of UNESCO will consider the matter at its 11th session to be held in Paris in November-December 1960.

Illustrative of the world's concern with the disposal of radioactive wastes was the attention given to this subject in numerous meetings and by various working groups. Of special interest was the submission to the International Atomic Energy Agency (IAEA), in April 1960, of an *ad hoc* panel report *Radioactive Waste Disposal into the Sea*, with the hope expressed by its chairman that "... the work of the Panel will be of value for the member countries of the Agency and that it can also form a basis for negotiations regarding an international convention with the aim 'to prevent pollution of the sea by radioactive materials in amounts which would adversely affect man and his marine resources.'"

No attempt can be made even to enumerate other meetings held during the last year which had international attendance or international significance for fisheries workers, but it is worth noting the current emphasis on symposia or on carefully designed and coordinated meeting programs, i.e., the distinct trend away from meetings which merely serve as catch-all for a host of unsolicited and unrelated papers.

Examples of symposia we cite the Symposium on the Problems of Major Lakes (Tahara, August 1960) and the Symposium on Marine Biology and the Fisheries on the Coast of Africa (Cape Town, September 1960), both organized by the Commission for Technical Co-operation in Africa South of the Sahara/Scientific Council for Africa South of the Sahara (CCTA/CSA).

Examples of carefully planned programs with emphasis on solicited papers one may mention the Food and Agriculture Organization of the United Nations (FAO) World Scientific Meeting on the Biology of Sardines and Related Species (Rome, 1959) and a proposed Conference on Water Pollution Problems in Europe to be held in Geneva in 1961. The latter meeting is also an example of a useful trend—the union of agencies which sometimes have rather different fields of major interest) in joint sponsorship of meetings. Thus, the pollution meeting will be sponsored by the Economic Commission for Europe (ECE), FAO, the World Health Organization (WHO), and the IAEA.

INTERNATIONAL FISHERIES COMMISSIONS AND COUNCILS

The continued increase in number and strengthening in importance of international fisheries commissions and councils is noted. One of these bodies, the International Council for the Exploration of the Sea (ICES) founded in 1902. Since then at least 14 more have been established and there is no doubt of more. A list of those known to this committee follows:

ICSM	International Commission for the Scientific Exploration of the Mediterranean Sea
ICERMP	Permanent Commission for the Conservation and Exploitation of the Maritime Resources of the South Pacific
EIFAC	European Inland Fisheries Advisory Commission
CM	General Fisheries Council for the Mediterranean
GLFC	Great Lakes Fisheries Commission
IATTC	Inter-American Tropical Tuna Commission
ICES	International Council for the Exploration of the Sea
NAF	International Commission for the Northwest Atlantic Fisheries

INPFC	International North Pacific Fisheries Commission
IPFC	Indo-Pacific Fisheries Council
IPHC	International Pacific Halibut Commission
IPSFC	International Pacific Salmon Fisheries Commission
IWC	International Whaling Commission
NPFSC	North Pacific Fur Seal Commission
PCIFC	Permanent Commission of the International Fisheries Convention 1946 (This may be succeeded by a Commission of the new International Northeast Atlantic Fisheries Convention.)

The activities of most of these groups are well-known and their reports readily obtainable. Therefore, we shall single out for attention only the newest one—the European Inland Fisheries Advisory Commission (EIFAC), an FAO regional body, whose initial meeting was held in Dublin in April 1960. With a present membership of 16 nations it provides, for the first time in history, an opportunity for the inland fisheries workers of Europe to come together for discussion and to promote action on problems such as those concerned with fish culture, surveys of fishing waters, appraisals of their fish populations, and water pollution control.

Studies are now in progress to explore the possibilities of establishing two other regional consultative fisheries bodies, one for the West African Region and another for the Western South Atlantic.

TECHNICAL ASSISTANCE TO DEVELOPING COUNTRIES

Assistance in the form of technical advice, surveys, fellowships, training centers, and the provision of funds for equipment and fisheries development has continued.

Noteworthy in this respect, as they have been in the past, are the continuing programs of such agencies as FAO under the Expanded Technical Assistance Program (ETAP) of the United Nations, the International Cooperation Administration (ICA) of the United States, the Colombo Plan for Cooperative Economic Development in South and South-East Asia, in which Canada has played such a large part, and the Norwegian Foundation for Assistance to Underdeveloped Countries.

Collaboration among the assisting agencies has often increased the effectiveness of their individual contributions. Here is one such example. In 1959 the Philippines asked FAO to send an expert to aid in building up its inland fisheries program. It was soon evident to this expert (an American and an AFS member), that a well-trained foreign assistant would be of the greatest aid and that a sizeable store of equipment was necessary to build up a combined fisheries and limnological laboratory. Unfortunately, neither the budget of the country nor of the Technical Assistance Board had made provision for these, but through the German government's Assistant Expert Scheme and the Colombo Plan both an assistant and a generous supply of equipment were provided.

Trends in the development of the technical assistance programs are difficult to predict. However, there is a growing awareness of the need for long-continued projects and greater emphasis on training programs. Except in certain specialized cases, the days of the foreign "expert" who makes a quick survey of the situation, writes his report, and leaves—often never to return—appear numbered. There is thus a need for the development of a cadre of well-trained fisheries men interested in devoting a considerable number of years to giving technical assistance, most of which is really technical "education."

The origin of the United Nations Special Fund with its capacity for large-scale assistance is already pointing toward the development of long-continuing projects, some with elaborate structure, and with emphasis on the combination of many resources and many skills. The first of such projects in the fisheries field was initiated during 1960 by the establishment of a Marine Resources Research Institute in Peru and more of them are following closely behind in other countries.

INTERNATIONAL SURVEYS

Plans were further consolidated this year for the start of one of the greatest oceanographic surveys, the International Indian Ocean Expedition, to explore what is said to be the world's least-known oceanic area covering one-seventh of the earth's surface. Coordinated by SCOR (the Special Committee on Oceanic Research) of the International Council of Scientific Unions (ICSU), it will be conducted as a cooperative effort of about a dozen nations. While its importance to fisheries is not being emphasized by the Commit-

tee, it is obvious that the information collected will have decided value to fishery scientists who have long felt that the resources of the Indian Ocean were neglected.

With respect to fresh-water surveys, notes the inauguration of a long-term limnological survey of the Danube River system. Of all the great river systems of Europe, the Danube has suffered the least change in its natural regimen. The survey seeks a thorough understanding of the biology, bacteriology, hydrography, physics, and chemistry of the river in order to relate this knowledge to practical problems concerned with fisheries, waste disposal, the construction of dams, fish passage, *et cetera*. Scientists from the Danube states (Austria, Bulgaria, Czechoslovakia, Germany, Hungary, Romania, the USSR, and Yugoslavia), as well as from Belgium, the Netherlands, Switzerland, the USA, FAO, and WHO will be on the initial voyage of a floating laboratory proceeding from Vienna to the Black Sea in September 1960.

The Danube study has long been planned by the Arbeitsgemeinschaft Donauforschung, a section of the International Association of Limnology (IAL), whose members are largely interested in the study of fresh waters, environmental sanitation, and fisheries. In spite of the members of the group conducting the study have generally compatible interests, and fisheries aspects receive high recognition from the supporting agencies. In many parts of the world, however, it is characteristic for fisheries to occupy an inferior or forgotten position in the hierarchies of governmental organizations and this position is reflected in the lack of recognition of their importance in the planning or development of land- and water-related projects. Even though the situation may have improved in North America, any complacency on the part of fisheries interests would still be dangerous. In most parts of the undeveloped world it is imperative that very positive steps be taken to ensure recognition of fisheries' values whenever river-basin development is contemplated. Plans for such development are on the drawing boards for most of the great rivers of the world, the Nile, the Congo, the Mekong, the Zambesi and others, and the immensity of the plans and the possible changes in the fishery resources are overwhelming. For example, the newly impounded Kariba Lake on the Zambesi, with its area of 1,300,000 acres and capacity of 110 million acre-feet, dwarfs any other reservoir in

and has a tremendous fishery resource potential.

It is encouraging, therefore, to see that several recent surveys designed to study international river basins with special reference to potentialities of water resource development have included fisheries experts as team members of the team along with the geographers, agriculturists, foresters, and economists. The FAO survey of the Mekong River (Cambodia, Laos, Viet-Nam, and Thailand) and the just-begun ICA/FAO survey of the Western Region of Nigeria are examples.

What has been neglected in this most preliminary résumé of a few of the significant developments in the field of international fisheries? We have spoken primarily of national and international organizations and the unalphabetized groups, some of which have been so long or so alphabetized that one tends to forget that their plans and their actions stem from the thoughts and endeavors of the men comprising them.

What of these men? They represent a host of nations. A considerable number are members of this Society. Those men from the tropics who are associated with the international fisheries commissions work closely with men from countries other than their own, and in so doing can achieve a better understanding of the intricacies of international problems and the importance of cooperative endeavor. Those men engaged in active field work under technical assistance programs have a satisfaction of being of genuine service in improving conditions in the less fortunate countries and have the added opportunity of seeing new lands and new peoples.

There is probably no more compelling problem today than how to achieve a better understanding of our fellow men. And the direct contact between men of many nations and of many races afforded fisheries workers through their participation in international endeavor is one of the basic ways to attain mutual understanding. (At the very least it should afford enlightenment that there are differences to be reconciled.)

Such contact need not be long nor is it in any way confined to the international fisheries worker. The university professor aids international relations whenever he trains a foreign student, as does any national, state, or municipal fisheries department which provides a study tour for the visitor from overseas. Similarly, the fisheries librarian who makes arrangements for the exchange of

periodicals or gifts of books and papers to the institutes of other countries is of assistance. And finally, each individual member of our Society can aid by being responsive to the requests for help that come from his fellow workers, on whatever continent they may be.

We realize that we are repeating a suggestion given in the report of the Committee at the 88th meeting of the American Fisheries Society. It can bear repeating.

Report of Committee on Commercial Fisheries

SETON H. THOMPSON

The commercial fishery resources and their utilization, throughout history, have been primary contributing factors to international controversies and disputes. In recent years, however, there has been a determined effort, especially among countries in the northern hemisphere, to solve these problems through bilateral or multilateral agreements before they become acute. This year has been significant for the efforts of many nations to reach agreement on principles of high seas resource utilization, and to create a climate of international understanding which would promote fisheries production.

The World Conference on Sardines convened representatives of 30 countries in Rome, and concluded that there was no evidence of overfishing sardine stocks, but instead that production could actually be increased from known stocks. Delegations representing the governments of the United States and Japan, supported by advisory groups from the tuna industry, met in Japan to explore the frictions and difficulties interfering with the full flow of economic benefit for both countries from the tuna resource, with acknowledged beneficial results. Early in 1960 a second World Conference met at Geneva on the questions of how far a nation's sovereignty should extend seaward from its shores, and the rights of the coastal nations in the control of ocean fisheries contiguous to their territorial seas. Still another World Conference, scheduled for 1961, is in the planning stage now to explore the unique nutritional value of fish and shellfish. This world-wide attention focused on the commercial fisheries could drastically influence productivity and yield, and therefore must be considered in any review of this subject.

The highlights of the 1959 fisheries harvest are outlined below. Additional details can be obtained by consulting the annual statistical publications of the United States and Canada.

UNITED STATES

The harvest of 5.1 billion pounds of fish and shellfish in 1959 was second only to the record production of 1956. The major contributor to this very large catch was the new record yield of 2.2 billion pounds of menhaden which more than offset the continued decline in the catch of groundfish.

For the first time the catch of fish for the manufacture of industrial products exceeded the quantity taken for human food, and the supply of fish meal and solubles established a new record. While the pack of canned tuna was close to the 1958 record of 14 million cases, the total pack of canned fishery products was considerably smaller than in 1958, and the pack of salmon was the smallest since the turn of the century.

Imports of tuna, shrimp, and groundfish fillets established new records. Forty-three percent of the 1959 United States supply of fish was obtained from imports, whereas 10 years earlier imports accounted for only 18 percent.

The Food and Agriculture Organization recently compiled some revealing statistics of the world catch of fishery products for the period 1950 to 1958. During this period the European catch of fishery products increased 23 percent; the USSR 61 percent; the African nations 72 percent; Asia 129 percent; and South America 181 percent. By contrast, the catch in the United States increased only 1 percent, and in other North American countries, only 9 percent. Further development, particularly in Asia and the underdeveloped countries, leaves little doubt that North American markets will be sought for the higher priced items, such as shrimp, in these increased catches.

CANADA

Canada's production of 2,064,600,000 pounds of fish and shellfish in 1959 was exceeded only twice in the past decade; in 1956 when 2,203,300,000 pounds were harvested, and in 1950 when the take was 2,122,300,000 pounds.

As in past years the bulk of the year's production was from the Eastern seaboard provinces, where the 1959 catch of 1,330,600,000

pounds exceeded the previous year's catch by over 100 million pounds. The Pacific Coast production, however, was some 36 million pounds below that of 1958. The fresh-water fisheries yielded 115 million pounds, approximately the same as in 1958.

Groundfish continue to be the most important on the Atlantic coast, where cod alone contributed slightly over 642 million pounds to the year's total. This production is in contrast to only some 7 million pounds on the Pacific coast, where the total groundfish catch was only some 43 million pounds. Here the important fisheries are the herring and salmon.

Although the market value of Canada's fish and shellfish production for 1959 has not yet been published, it should be well over \$200 million. When it is realized that the value of the exports of these products is approximately \$148 million, the dependence on export markets will be appreciated. The bulk of Canada's exports go to the United States.

GENERAL

Exploratory fishing operations by the United States Bureau of Commercial Fisheries have led to the development of new fisheries for smelts, chubs, and other rough fish with otter trawls instead of gill nets in Lake Erie and Lake Michigan; hard clams and scallops off the North Carolina and Florida coasts; and the use of improved methods such as the fish bubble curtain for intercepting sardines in Maine, and special trawl gear for the capture of red snappers and industrial bottom fish in the Gulf of Mexico.

Chemical control of lampreys has made a substantial reduction in the populations of this predator in Lake Superior, and control methods are being expanded to Lake Michigan and Lake Huron. Plans are in preparation now to rehabilitate the lake trout stocks that were decimated by lampreys.

The voluntary program for inspection and certification of fishery products in the United States has grown rapidly. Nine standards are now in effect; two are in process, and several are in the developmental stage. Thirty-four fish-processing plants are under continuous U.S.D.I. inspection by about 40 inspectors, and lot inspection also is available in a number of major cities.

The Gulf shrimp industry was in difficulty during 1959. Prices were down, inventory up, and imports were arriving in record volume. In cooperation with the industry,

non-wide promotional effort was undertaken by the Bureau of Commercial Fisheries to beneficial results, and this industry is back to normal. A similar cooperative effort is presently under way with respect to the oyster and scallop industry in New England, and equally satisfying results are becoming apparent.

The fisheries loan fund established in 1956 to upgrade the United States fishing fleet has strengthened the industry has processed a total of 587 applications and approved loans aggregating \$7,712,000, of which New England received 40 percent, California 25 percent, South Atlantic and Gulf 19 percent, Pacific Northwest 10 percent, Alaska 3 percent, with the balance to the Great Lakes States and Hawaii.

The control of commercial fishery operations, with conservation as the primary objective, in many instances has forced the use of inefficient and costly methods of capture in many parts of the United States. To hold on the total catch of a species in the face of a growing group of fishermen, regulations have been imposed that limit the kind and size of gear, the number of days it can be used, the hours of fishing, and the places where fishing can be carried on. The net result is higher prices to the consumer for what often is a relatively poor quality product by comparison with the product of efficient, large-scale fishing methods.

In order that the commercial fisheries may maintain their position of importance in our economy, it is the recommendation of this committee that the Society through an *ad hoc* committee examine the status of legislative and regulatory controls now in effect with a view to designing model conservation measures for our major fisheries.

pollution control; (3) increases or decreases in facilities, equipment, and staff engaged in pollution research, investigations, and administration; (4) significant developments or accomplishments in pollution abatement and control; (5) research programs now in operation; (6) increase or decrease in research staff; (7) significant research findings; and (8) reports and publications of research on water pollution.

At the 1959 meeting of the Society the Pollution Committee became an appointive committee and was enlarged so that more complete coverage of the United States and Canada could be secured. In the past some members of the Committee have felt that the areas assigned to them were so large and entailed so much work that they could not adequately cover the areas. Further, they were not acquainted with all the work being carried on in their area. In order to meet this problem the United States was divided up into nine areas which were judged to be units and would lend themselves to coverage by one individual. These areas are: (1) New England, comprising the six New England states; (2) Mid-Atlantic area, consisting of New York, Pennsylvania, West Virginia, Delaware, and New Jersey; (3) Southeast area, consisting of the States of Virginia, Maryland, North Carolina, South Carolina, Georgia, and Florida; (4) Mid-South, consisting of the States of Arkansas, Louisiana, Mississippi, Alabama, Tennessee, and Kentucky; (5) North-Central, consisting of Minnesota, Wisconsin, Michigan, Illinois, Indiana, and Ohio; (6) Great Plains, consisting of North Dakota, South Dakota, Nebraska, Kansas, Iowa, and Missouri; (7) Southwest, consisting of Oklahoma, Texas, New Mexico, Arizona, and Mexico; (8) Inter-mountain, consisting of Idaho, Montana, Utah, Colorado, Wyoming, and Nevada; and (9) Pacific, consisting of Alaska, Hawaii, Washington, Oregon, and California.

Canada was divided into areas, an eastern area consisting of the Provinces of Ontario, Quebec, New Brunswick, Nova Scotia, Labrador, and Newfoundland, and a western area, consisting of the Provinces of Manitoba, Saskatchewan, Alberta, British Columbia, Northwest Territory, and the Yukon.

In making these surveys, questionnaires were sent to all administrative, control, and research groups, federal, provincial, and state. Questionnaires have also been sent to universities carrying on some research in water pollution or in fields related to water pollu-

Report of Committee on Water Pollution

CLARENCE M. TARZWELL

During the past several years the Pollution Committee of the American Fisheries Society has been engaged in a survey of research in the field of water pollution and a compilation of trends in the enforcement of pollution legislation. The specific objective of the Committee has been to report on the following: (1) pollution problems and their relative importance; (2) new regulations and laws for

tion, to private research agencies, and to industries. At least some data have been received from all states and provinces of the United States and Canada. These data have been summarized on large sheets with enforcement data on one sheet and research data on another. Data have been assembled by states and provinces with a special section for federal agencies. The complete report has been mimeographed and will be available to interested parties upon request to the Secretary-Treasurer.

The findings in this report, which covers the period 1958-59, differ somewhat from the first report which covered the period 1955, 1956, and 1957. In the report for 1958-59 sewage pollution is not always considered to be of first importance. Satisfaction has been widely expressed concerning the United States' federal aid program for the construction of sewage treatment facilities. Some feel that this program has been of great benefit in reducing sewage pollution problems. There has been a definite increase in pesticide pollution problems with numerous fish kills reported. It is apparent that pesticides are assuming a much more important place among various causes of pollution. Incomplete returns of a fish-kill survey being carried out by the U. S. Public Health Service indicate

that during a 4-month period 38 percent of fish kills were due to pesticides. In southern state 93 percent of reported kills were due to pesticides.

There has been some increase in pollution investigations and research activity. In some states there has been a decrease in activity whereas in others activities have remained about constant. In the area under consideration as a whole it is evident that research in the biology of water pollution is increasing. One of the outstanding developments is the widespread use of bioassays for the detection of toxic wastes, the evaluation of the overall toxicity of certain effluents, the detection of unit processes which may be contributing to toxicity, and evaluation of industrial waste problems and the amount of treatment needed.

There has been an increasing awareness of the importance of silt as a pollutant and the potential pollutional effects of other materials washed in from the watershed. This concept is somewhat new since generally pollutants are regarded as originating from a point source. However, silt, radioactivity due to fallout, and pesticides enter a stream from the entire watershed and are thus not amenable to conventional methods of collection and treatment. Control of such materials must be exercised at their source.

REGISTERED ATTENDANCE

NINETIETH ANNUAL MEETING

ers, Maxine, Colorado
 en, J. F., Washington, D. C.
 man, William, Oklahoma
 ord, William, Montana
 erson, H. John, Nebraska
 erson, Holger, South Dakota
 ews, George, Colorado
 riano, Donald, Utah
 elovic, Joe W., Utah
 ason, Clinton, Washington, D. C.

us, Leland C., Colorado
 er, C. W., Colorado
 win, Ruth E., Wisconsin
 ks, F. G., Florida
 ker, Roy E., New Mexico
 abby, Jean, Oregon
 abby, Tom, Oregon
 hart, Roger A., Colorado
 rows, P. T., Colorado
 l, Fred R., Wyoming
 er, Eugene H., Iowa
 , Ada, Colorado
 nett, Carey H., New Mexico
 nett, George W., Illinois
 son, Norman G., Utah
 art, Charles V., Nebraska
 n, Larry, New Jersey
 n, Ed W., Texas
 ell, A. E., Colorado
 shears, Robert L., New Mexico
 lger, J. A., North Carolina
 lges, W. R., Colorado
 wn, Edward H., Jr., Ohio
 ant, Charles R., Colorado
 k, Homer, Illinois
 knam, George W., Maine
 de, G. Edward, Missouri
 kley, Ross V., Utah
 khard, Walter T., Colorado
 ner, Charles C., Oklahoma
 ress, Ralph M., Missouri
 stall, Pat, New Zealand
 well, Robert W., Minnesota
 er, Robert, California
 d, I. B., Alabama
 d, W. Keith, Florida

oun, Alex, California
 bine, W. F., Michigan
 ander, Kenneth D., Iowa
 son, Clarence O., Iowa
 penter, Ralph G., New Hampshire

Carter, Bernie, Kentucky
 Chipman, Jack R., Idaho
 Churchman, J. W., Saskatchewan
 Clark, Jess R., Utah
 Clark, Minor, Kentucky
 Clements, Mannen, New Mexico
 Coates, J. A., Idaho
 Cobb, Roland H., Maine
 Cook, A. B., Michigan
 Cook, Eugene, Colorado
 Cope, Oliver B., Colorado
 Cornell, J. H., North Carolina
 Cottam, Clarence, Texas
 Couldwell, George E., Saskatchewan
 Cox, Nelson, Arkansas
 Crane, Harold S., Utah
 Croker, Richard, California
 Cronan, John M., Rhode Island

Davis, George W., Vermont
 Davis, Jackson, Michigan
 Dawson, Leo H., Nebraska
 Day, Albert M., Pennsylvania
 Dickson, Fred J., Georgia
 Dieffenbach, William H., Colorado
 Dobie, John, Minnesota
 Donaldson, Lauren R., Washington
 Donoho, Clyde K., Nebraska
 Dowd, James C., South Dakota
 Drummond, Robert A., Colorado

Eddy, Gerald E., Michigan
 Edstrom, R. M., Minnesota
 Eicher, George J., Oregon
 Eiserman, Fred, Wyoming
 Eling, Carl H., Washington
 Elliott, Robert R., Colorado
 Ellis, Wade, Nebraska
 Evans, Robert L., Colorado

Feltner, George, Colorado
 Fields, Paul E., Washington
 Findlay, John D., Washington, D. C.
 Finnell, Larry M., Colorado
 Flowers, Jay C., Ohio
 Fogle, Ned E., South Dakota
 Foster, David I., Arizona
 Foster, Glen R., Nebraska
 Frank, Rudy, Connecticut
 Fredine, Gordon, Washington, D. C.
 French, Tom E., Colorado
 Frome, Harry, New Jersey
 Funk, John L., Missouri

Gaffney, John J., Montana
 Galligan, James, Connecticut
 Garlick, Lewis R., New Mexico
 Gatlin, John C., New Mexico
 Gentry, Glen, Tennessee
 Goede, Ronald W., Utah
 Goldman, Charles R., California
 Gordon, Seth, California
 Goss, Earle G., Oregon
 Gottschalk, John S., Massachusetts
 Graham, Charles, Washington
 Gray, Joe, Nebraska
 Greenbank, John, Colorado
 Greene, A. F. C., Colorado
 Gregg, Frank, Illinois
 Grenoble, J. W., Pennsylvania
 Gresh, Arthur J., Colorado
 Gresh, Walter A., Georgia
 Gross, Richard, New Jersey
 Gudjonsson, Thor, Iceland
 Gutermuth, C. R., Washington, D. C.

Hale, Arthur S., Colorado
 Hamilton, Roy, Oregon
 Hanson, John E., Utah
 Harlan, James R., Washington, D. C.
 Harmic, Jay L., Delaware
 Hasler, Arthur D., Wisconsin
 Hatch, Richard W., Alaska
 Hauck, Forrest R., Idaho
 Haupt, Walter, Wisconsin
 Hay, Keith G., Colorado
 Hayes, Charles R., Colorado
 Hazzard, Albert S., Pennsylvania
 Heinen, Edward T., Florida
 Helm, William T., Utah
 Hemphill, Jack E., New Mexico
 Henderson, Charles, Kansas
 Hile, Ralph, Michigan
 Hill, Ralph R., Colorado
 Hinde, J. Nelson, Illinois
 Hiner, L. E., North Dakota
 Hjelte, Charles E., Colorado
 Hockstrasser, Herbert, Colorado
 Hoffman, Dale A., Colorado
 Holland, W. L., Alabama
 Holton, George D., Montana
 Hooper, Frank F., Michigan
 Hoppe, Richard A., Colorado
 Horak, Donald L., Colorado
 Houser, Al., Oklahoma
 Howard, H. C., Nebraska
 Howell, John H., Michigan
 Hudoba, Michael, Washington, D. C.
 Huish, Melvin, Florida
 Hulsey, Andrew H., Arkansas
 Hunn, William F., Colorado

Hunter, Gilbert N., Colorado
 Huston, Joe E., Montana
 Hutchens, Lynn H., New Mexico
 Hutchinson, Sam, Washington
 Hutmacher, Mrs. O. S., Colorado

Illige, Denis J., Colorado
 Irwin, W. H., Oklahoma
 Ivy, Glenn H., Texas

Jackson, Sam, Jr., Oklahoma
 Janzen, Daniel, Washington, D. C.
 Jenkins, Robert M., Washington, D. C.
 Jester, Douglas B., New Mexico
 Jiacoletti, S. J., Wyoming
 Johnson, R. E., Washington, D. C.
 Jones, David J., Nebraska
 Jones, Robert A., Colorado
 Joslin, Verne E., Minnesota

Katz, Max, Washington
 Keeton, Dee, Iowa
 Kelly, Henry J., New Jersey
 Kempers, Bert, Colorado
 Kendle, Earl R., Nebraska
 Kennedy, A. S., Massachusetts
 Kimball, Ted, Utah
 Kittams, Walter H., Nebraska
 Klein, William D., Colorado
 Kozicky, Edward L., Illinois
 Kramer, Robert H., Minnesota
 Kutkuhn, Joseph H., Texas

Lagler, Karl F., Michigan
 Langenfeld, Edward P., Wisconsin
 Larimore, Weldon, Illinois
 Larsen, Howard N., Alabama
 Larsen, Margaret, Colorado
 Latimore, Robert E., New Mexico
 Lawrence, Leo A., New York
 Lawrence, W. Mason, New York
 Laythe, Leo L., Oregon
 Leach, Howard R., California
 Leman, Bernie, Washington
 Lemons, David G., Colorado
 Lenz, Gerhard, Nebraska
 Leonard, Ross, Idaho
 Levine, Daniel B., Washington, D. C.
 Likes, John, Colorado
 Little, Ralph G., New Mexico
 Lynch, T. M., Colorado

MacKay, H. H., Ontario
 Marvich, E. S., Alaska
 Massie, T. N., North Carolina
 Massmann, William H., Virginia
 McCarraher, Bruce, Nebraska

Laughlin, Charles L., Massachusetts
 Leary, Edward, Washington
 Natt, Travis, Tennessee
 Nicks, Robert C., Washington
 Novak, Larry, New Mexico
 Over, William H., Iowa
 Penbach, Cliff, Washington
 Pett, James W., Michigan
 Pody, Harold L., Florida
 Pore, George C., Georgia
 Pore, Richard L., Colorado
 Porgan, H. R., North Dakota
 Parris, A. G., Missouri
 Parris, John H., Colorado

Paton, William T., Jr., Oklahoma
 Payre, Richard I., New Mexico
 Pearson, Don S., Utah
 Pearson, Wesley C., Colorado
 Peabold, John M., Utah
 Peabody, John D., Louisiana
 Peabols, Hudson M., Tennessee
 Pirelli, Ross F., New York
 Pirmann, Rolf B., Colorado
 Poles, Donald, Texas
 Poling, Donald, Colorado
 Polross, John J., Virginia
 Polwood, Robert, Texas

P. O. E., Nebraska

Pomeroy, Glen D., Illinois
 Poutzke, Clarence, Alaska
 Punter, E. L., Saskatchewan
 Pufford, Joseph, Virginia
 Pury, Ted, Oregon
 Pusey, Larry, Wyoming
 Phillips, Arthur M., Jr., New York
 Piskering, Quentin H., Ohio
 Piskup, John, Missouri
 Preece, Robert A., Arkansas
 Pummer, T. O., Colorado
 Puskett, Charles A., Missouri
 Pual, Cal, Colorado

Puadall, Jack E., Colorado
 Puavley, William, Utah
 Puarnolds, Robert, Colorado
 Puode, William J., Nebraska
 Puogs, Carl D., Oklahoma
 Puordan, Laurence E., Colorado
 Puach, Lee S., Ohio
 Puolofs, Eugene W., Michigan
 Puoe, Earl T., Iowa
 Puoss, Mylan E., Wisconsin
 Puot, George S., Colorado

Royce, William F., Washington
 Ruhr, Gene, Tennessee
 Ryder, R. A., Colorado

Saalfeld, Robert W., Michigan
 Saksena, Vishnu P., Oklahoma
 Schafer, Harry, Louisiana
 Schaub, Paul, Colorado
 Schmulbach, James, South Dakota
 Schneberger, Edward, Wisconsin
 Schneider, P. W., Oregon
 Schoettger, Richard A., Colorado
 Schoonover, Roy, Kansas
 Schultz, Herman, Jr., Colorado
 Schumacher, Robert E., Minnesota
 Scott, Beverly, Colorado

Seaman, E. A., Virginia
 Seaman, Wayne R., Colorado
 Shaw, E. L., Colorado
 Shaw, Paul A., California
 Shields, James T., South Dakota
 Sigler, William F., Utah
 Simmons, J. W., Florida
 Simpson, James C., Idaho
 Skiff, J. V., New York
 Skud, Bernard E., Texas
 Smith, Curt P., Alberta
 Smith, Lloyd L., Jr., Minnesota
 Solman, Victor E. F., Ontario
 Speaker, E. B., Iowa
 Sprecher, George E., Wisconsin
 Sprugel, George, Washington, D. C.
 Stafford, Roy A., Oklahoma
 Steen, M. O., Nebraska
 Stewart, R. Keith, South Dakota
 Strawn, Kirk, Arkansas
 Stroud, Richard H., Washington, D. C.
 Stula, Michael J., Connecticut
 Sullivan, John, Pennsylvania
 Surber, Eugene W., Georgia
 Swanson, Mrs. Marvin, South Dakota
 Swartz, Albert, Washington, D. C.
 Swenson, Hjalmar, Minnesota
 Swift, Ernest, Wisconsin
 Swift, Lloyd W., Washington, D. C.

Tack, Peter I., Michigan
 Taliaferro, Rex, Colorado
 Tanner, Howard A., Colorado
 Tarzwell, Clarence M., Ohio
 Taylor, Glenn E., Colorado
 Terrill, Harold V., Missouri
 Thomas, Robert, Nebraska
 Thomas, Ron C., Alberta
 Thompson, Fred A., New Mexico
 Thompson, Paul L., Washington, D. C.
 Thompson, William H., Oklahoma

Thorpe, Lyle M., Connecticut
Tiemeier, Otto W., Kansas
Tobin, Lois, Colorado
Tolman, Con, Colorado
Toole, Marion, Texas
Topel, Hubert C., Virginia
Tunison, Abe, Washington, D. C.

Underhill, A. E., New Jersey

Van Cleve, Richard, Washington
Van der Walker, John G., Texas
Van Oosten, John, Michigan

Wade, Gerry, Maine
Wallis, O. L., Virginia
Ward, Claud M., Oklahoma

Watkins, H. B., Alberta
Watson, Nelson, Ontario
Weber, Don T., South Dakota
Wenzel, Walter J., New Mexico
Wescoatt, Ivan I., Colorado
Westerman, Fred A., Michigan
Wheeler, John A., Colorado
Whitney, Arthur N., Montana
Whitney, Richard R., Maryland
Wilder, Norman G., Delaware
Williams, Fred T., Wyoming
Williams, Raymond M., Pennsylvania
Willoughby, Harvey, South Dakota
Wiltzius, William, Colorado
Workman, Gar W., Utah
Wurm, Donald W., Colorado

Zeller, Howard, Georgia